Premier Reference Source

Imagination, Creativity, and Responsible Management in the Fourth Industrial Revolution

Ziska Fields, Julien Bucher, and Anja Weller

IGI Global
DISSEMINATOR OF KNOWLEDGE

Imagination, Creativity, and Responsible Management in the Fourth Industrial Revolution

Ziska Fields
University of Johannesburg, South Africa

Julien Bucher
Chemnitz University of Technology, Germany

Anja Weller
Saxon State Ministry of Education and Cultural Affairs, Germany

A volume in the Advances in Logistics, Operations, and Management Science (ALOMS) Book Series

Published in the United States of America by
IGI Global
Business Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA, USA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

Library of Congress Cataloging-in-Publication Data

Names: Fields, Ziska, 1970- editor. | Bucher, Julien, 1985- editor. | Weller, Anja, 1985- editor.
Title: Imagination, creativity, and responsible management in the fourth industrial revolution / Ziska Fields, Julien Bucher, and Anja Weller, editors.
Description: Hershey, PA : Business Science Reference, [2019]
Identifiers: LCCN 2018058917| ISBN 9781522591887 (hardcover) | ISBN 9781522591894 (ebook) | ISBN 9781522591924 (softcover)
Subjects: LCSH: Management. | Creative ability in business. | Social responsibility of business.
Classification: LCC HD31.2 .I53 2019 | DDC 658.4/08--dc23 LC record available at https://lccn.loc.gov/2018058917

This book is published in the IGI Global book series Advances in Logistics, Operations, and Management Science (ALOMS) (ISSN: 2327-350X; eISSN: 2327-3518)

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

Advances in Logistics, Operations, and Management Science (ALOMS) Book Series

ISSN:2327-350X
EISSN:2327-3518

Editor-in-Chief: John Wang, Montclair State University, USA

MISSION

Operations research and management science continue to influence business processes, administration, and management information systems, particularly in covering the application methods for decision-making processes. New case studies and applications on management science, operations management, social sciences, and other behavioral sciences have been incorporated into business and organizations real-world objectives.

The **Advances in Logistics, Operations, and Management Science** (ALOMS) Book Series provides a collection of reference publications on the current trends, applications, theories, and practices in the management science field. Providing relevant and current research, this series and its individual publications would be useful for academics, researchers, scholars, and practitioners interested in improving decision making models and business functions.

COVERAGE

- Marketing engineering
- Information Management
- Production Management
- Computing and information technologies
- Services management
- Networks
- Organizational Behavior
- Risk Management
- Finance
- Operations Management

IGI Global is currently accepting manuscripts for publication within this series. To submit a proposal for a volume in this series, please contact our Acquisition Editors at Acquisitions@igi-global.com or visit: http://www.igi-global.com/publish/.

The Advances in Logistics, Operations, and Management Science (ALOMS) Book Series (ISSN 2327-350X) is published by IGI Global, 701 E. Chocolate Avenue, Hershey, PA 17033-1240, USA, www.igi-global.com. This series is composed of titles available for purchase individually; each title is edited to be contextually exclusive from any other title within the series. For pricing and ordering information please visit http://www.igi-global.com/book-series/advances-logistics-operations-management-science/37170. Postmaster: Send all address changes to above address.

Titles in this Series

For a list of additional titles in this series, please visit:
https://www.igi-global.com/book-series/advances-logistics-operations-management-science/37170

Handbook of Research on Urban and Humanitarian Logistics
Jesus Gonzalez-Feliu (Ecole Nationale Superieure des Mines de Saint-Étienne, France) Mario Chong (Universidad del Pacifico, Peru) Jorge Vargas Florez (Pontificia Universidad Católica del Perú, Peru) and Julio Padilla Solis (Universidad de Lima, Peru)
Information Science Reference • ©2019 • 497pp • H/C (ISBN: 9781522581604) • US $295.00

Industry 4.0 and Hyper-Customized Smart Manufacturing Supply Chains
S.G. Ponnambalam (University Malaysia Pahang, Malaysia) Nachiappan Subramanian (University of Sussex, UK) Manoj Kumar Tiwari (Indian Institute of Technology Kharagpur, India) and Wan Azhar Wan Yusoff (University Malaysia Pahang, Malaysia)
Business Science Reference • ©2019 • 347pp • H/C (ISBN: 9781522590781) • US $225.00

Additive Manufacturing Technologies From an Optimization Perspective
Kaushik Kumar (Birla Institute of Technology Mesra, India) Divya Zindani (National Institute of Technology Silchar, India) and J. Paulo Davim (University of Aveiro, Portugal)
Engineering Science Reference • ©2019 • 350pp • H/C (ISBN: 9781522591672) • US $205.00

Handbook of Research on Women in Management and the Global Labor Market
Elisabeth T. Pereira (University of Aveiro, Portugal) and Paola Paoloni (Sapienza University of Rome, Italy)
Business Science Reference • ©2019 • 423pp • H/C (ISBN: 9781522591719) • US $285.00

Managing Operations Throughout Global Supply Chains
Jean C. Essila (Northern Michigan University, USA)
Business Science Reference • ©2019 • 358pp • H/C (ISBN: 9781522581574) • US $205.00

For an entire list of titles in this series, please visit:
https://www.igi-global.com/book-series/advances-logistics-operations-management-science/37170

IGI Global
DISSEMINATOR OF KNOWLEDGE

701 East Chocolate Avenue, Hershey, PA 17033, USA
Tel: 717-533-8845 x100 • Fax: 717-533-8661
E-Mail: cust@igi-global.com • www.igi-global.com

Editorial Advisory Board

Table of Contents

Section 2
Creativity in the Fourth Industrial Revolution

Section 3
Responsible Management in the Fourth Industrial Revolution

Detailed Table of Contents

Human beings are the only mammals to be able to utilize high-level cognitive functions to build knowledge, innovate, and communicate their complex ideas. Imagination, creativity, and innovation are interlinked in the sense that one leads to the other. This chapter details the concepts of imagery, imagination, and creativity and their inter-relationships in the first section. Next, the author discusses the historical perspectives of imagination pertaining to the accounts of famous philosophers and psychologists like Aristotle, Kant, Hume, Descartes, Sartre, Husserl, and Wittgenstein. Section 3 and 4 present the neuro-biological correlates of imagination and creativity, respectively. Brain regions, neuronal circuits, genetic basis, as well as the evolutionary perspective of imagination and creativity are elicited in these sections. Finally, creativity and innovation are explored as to how they will contribute to knowledge build-up and advances in science, engineering, and business in the fourth industrial revolution and the imagination age.

This chapter regards itself with the verification of theses by American scientist Robert Root-Bernstein who through scientific work spanning decades was able to find support for the argument that a successful scientist is more likely to have an artistic avocation than their less successful counterparts. This chapter takes a close look at three studies by Root-Bernstein and goes on to try and affirm his findings by conducting and analyzing interviews with scientists that have an artistic avocation. The results of the study show that art offers an escape for scientists to reorganize their thoughts. Further, if scientists combine the two worlds of art and science, the scientists can directly benefit from their artistic avocation for their scientific work.

To compete in the workplace of the Fourth Industrial Revolution, cognitive skills development is critical. The traditional education system is not geared to prepare students for the demands of the future workplace and the disruptions of the Fourth Industrial Revolution and beyond. The objective of this chapter is to explore the development of cognitive skills in higher education with a specific focus on creativity. The chapter explains that higher education institutions need to place greater emphasis on developing cognitive skills and different types of intelligences to meet the demands of the future workplace. Fostering creativity is particularly important in this regard. The chapter presents two ways of assessing creativity and three techniques to develop this key skill in students. The author used qualitatively summarized evidence on the topic using informal and subjective methods to collect and interpret studies and secondary data.

Apart from the emergence of new technologies, the Fourth Industrial Revolution is characterized by demographic developments that will provoke fundamental changes in the labor markets of many industrialized countries. This situation will especially affect small and medium-sized enterprises (SMEs) that are based in rural regions with rapidly increasing numbers of retirees and an equally rapidly shrinking population of young people. If these companies want to maintain their levels of production in the Fourth Industrial Revolution, they will need to pursue new creative strategies for attracting the best talents. All of this is true for Saxony, a highly industrialized German region with a large percentage of SMEs that is hit hard by declining birth rates and high levels of emigration, and the East Asian society of Taiwan that faces similar challenges. At the same time, many well-educated members of the young generation in both regions feel disrespected, underpaid, and without prospects.

For a more integrative view on social, technical, and individual aspects of knowledge sharing and generation in virtual environments, the current contribution suggests a socio-technical framework based on distributed cognition theory and transactive memory systems. In combination, these well-established social theories provide theoretical foundations for describing and understanding how groups of individuals organize shared activities and interact with technology to store, retrieve, and use individual knowledge for common problem solving and innovation.

This chapter will provide insights into the positioning and manifestation of knowledge management in a digital native enterprise. The findings of the literature review will be enhanced with the findings from three use cases reflecting on the infliction point between knowledge management and work performed in the digital native enterprise. The aforementioned will enable early insights into the role and contribution of knowledge management in an ecosystem where people and devices are seamlessly connected and strategic decisions are needed in respect of the positioning and manifestation of knowledge management, as well as the skillfulness required by knowledge managers within the construct of the digital native enterprise.

Foreword

The book *Imagination, Creativity, and Responsible Management in the Fourth Industrial Revolution* addresses three interconnected aspects of the contemporary and future-oriented management education for the leaders and academics of tomorrow. First, it provides a connection with advanced digital technologies such as those of the Fourth Industrial Revolution and their interplay with business and society. This combination is important given because management is increasingly affected by, empowered through these technologies, and will be even more so in the coming future. Second, it introduces the concepts of imagination and creativity, which both require sustainable and responsible management practices and values beyond the single focus on short-term profit gains. These aspects are integrated in a unique way and are illuminated from a variety of perspectives such as philosophy, neuroscience, science fiction or humanities and social sciences in general. Shaping the future will require more transdisciplinary approaches that are already started to be developed in this book. Some indications such as the imaginative impact that artistic activity has on a scientist's achievement might be mentioned in this context.

This book could not be timelier. By focusing on creative, responsible and sustainable management practices, leaders and academics require the necessary skills and imagination to develop and make use of innovative technologies as well as to understand the impact of these technologies. To ensure responsible and sustainable management practices, they also need to be aware of the global impact of their decisions. Managers should, therefore, understand the impact of their business processes on the environment and use responsible, sustainable and globally applicable management practices to leverage the opportunities of the Fourth Industrial Revolution.

The book addresses various topics related to this context and critically reflects on the importance and impact of new digital technologies. By providing novel insights for the somewhat neglected roots of innovations such as imagination, which is exemplified in science fiction and methods for knowledge sharing and creation in virtual teams, the book enables much-needed guidance for students and scholars of innovation.

I wish all the credits, attention and success this book deserves for the authors. I am sure this unique compilation of interrelated concepts, especially the aspects of imagination, creativity and innovation nexus will pave the way for further productive research programs and will attract a lot of positive attention.

Stefan Huesig
Chemnitz University of Technology, Germany
June 2019

Preface

The Fourth Industrial Revolution is picking up pace and will continue to have a profound effect on humans, business activities and the planet (Schwab, 2019). To compete in this rapidly evolving environment, organizations need to understand the impact of the Fourth Industrial Revolution on all spheres of society and the world as a whole, to plan proactively for future demands and opportunities, and to create a society where mankind and the planet can thrive. This will require collaboration between policymakers, scientists, civil society, technology champions, investors and people in general. Schwab cited in Marr (2018) expresses concern that "decision-makers are too often caught in traditional, linear (and non-disruptive) thinking or too absorbed by immediate concerns to think strategically about the forces of disruption and innovation shaping our future" (p. 1). Schwab calls for all leaders and citizens to work together, to put people first, to empower them to work and thrive in the Fourth Industrial Revolution.

As we move through the Fourth Industrial Revolution, people are becoming more concerned about the potential benefits and risks of digital technology and its impact. People are worried about the extent, the implementation and the effect digital transformation will have on their privacy, jobs and welfare. There is also the concern of global inequalities due to the digital divide amongst developed and developing countries. People fear that limited access to digital technology will negatively affect their ability to live and interact in a global world. In addition, the climate crisis is causing people to doubt the positive impact of accelerated technological development on the planet.

Business managers will be expected to navigate organizations and employees through this unknown territory of digital transformation and disruption. People therefore need to be educated and empowered to live and work in the era of the Fourth Industrial Revolution (Marr, 2018) – and beyond. Education plays a huge role in preparing people for the future workplace and providing the necessary knowledge and skills. An essential part of this is the fostering of new skills and capabilities (Rodny-Gumede, 2019). Education institutions unfortunately cannot fulfil this task alone and need to be part of the collaborative efforts of governments, industries and societies. Schleicher cited in Al-Montser (2017) adds that people will need to continuously upgrade their qualifications and skills and become life-long learners to remain knowledgeable and employable.

Reinventing the future of work thus needs to be a whole-society effort – and finding long-term solutions will require ideas and initiative from every quarter. The World Economic Forum (2017) asserts that the cognitive abilities of humans are extremely important in the Fourth Industrial Revolution as humans have the ability to deal with complexity. Cognitive abilities will be critical as humans face challenges greater than ever before in human history as the planet remains under threat due to selfish ways and the ever-increasing impact of technology and automation.

This book explores how human imagination, creativity and responsible management can be used in the Fourth Industrial Revolution. The book takes a multidisciplinary perspective in its search for answers.

Imagination is a cognitive process which every human possesses. This capacity allows us to mentally create novel objects, people and ideas in our heads which are not perceived through the five senses. Imagination is the ability of the mind to build mental scenes, objects or events that do not exist (De Haas, 2014). Imagination, according to De Haas (2014) is "essential for anyone, especially for leaders, who not only have to lead people into the future but have to foresee the challenges not yet known that await mankind" (p. 3). Imagination is the lifeblood of great ideas and plays a vital role in human life and development. Human imagination is required to prevent the negative impact of unchecked technological advancement. Intellectual imagination is a conscious and deliberate process (Rush, 2018) that requires great effort and care. Imaginative fantasy is used to generate new ideas from scratch and is the soul of creativity.

Creativity is important for prosperity and economic growth (Hoffmann, Cropley, Cropley, Nguyen & Swatman, 2014). Creativity needs imagination, which is a key cognitive skill in the Fourth Industrial Revolution. Vandervelde (2018) explains that "creativity is tackling challenges, improving what exists today, and developing concepts determining our future". He adds that creativity's starting point is the idea that is generated while the end point is a concept that brings originality and value. Creativity, complex problem-solving skills and critical thinking are crucial to ensure that humans create and innovate technology responsibly to sustain the planet.

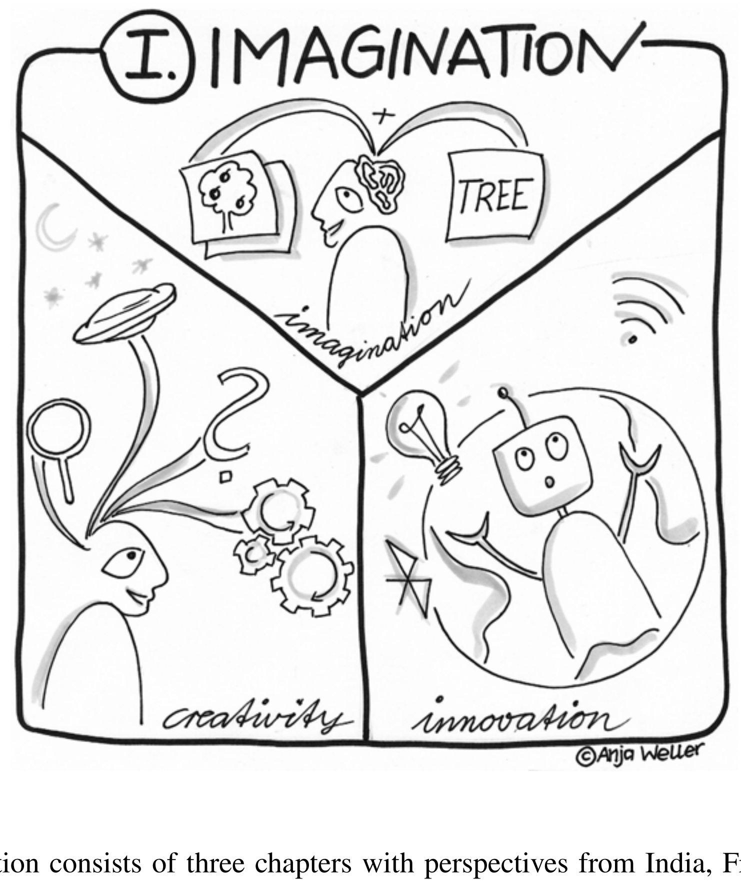
Never before has an ecological crisis presented as fundamental and serious a threat to humans at a global scale as climate change. Humans can no longer continue building capitalistic markets without consideration for the effect it has on the planet. Climate change has become real and in the Fourth Industrial Revolution, it will be more critical than ever before. Responsible management, using imagination and creativity to come up with better ways to overcome these difficulties, is essential – not only for prosperity but for survival. Wilhelm (2013) believes that climate change is a great challenge, but a solvable one, and business must be part of the solution. Every human has a role to play.

The book is divided into three sections.

SECTION 1: IMAGINATION IN THE FOURTH INDUSTRIAL REVOLUTION

"Imagination is the beginning of creation. You imagine what you desire, you will see what you imagine, and at last, you create what you will."— George Bernard Shaw

Figure 1.



This section consists of three chapters with perspectives from India, France and Germany.

Chapter 1, written by Rajashree Chaurasia (India), is titled “On the Principles of Imagination and Creativity: Philosophy, Neuroscience, and the 4IR.” The author explains that imagination, creativity and innovation are interlinked insofar as one leads to the other. The chapter examines the historical perspectives of imagination through the eyes of famous philosophers and psychologists such as Aristotle, Kant, Hume, Descartes, Sartre, Husserl and Wittgenstein. Chaurasia then explores the neuro-biological connection between imagination and creativity and explains how this will contribute to advances in science, engineering and business in the Fourth Industrial Revolution and the imagination age.

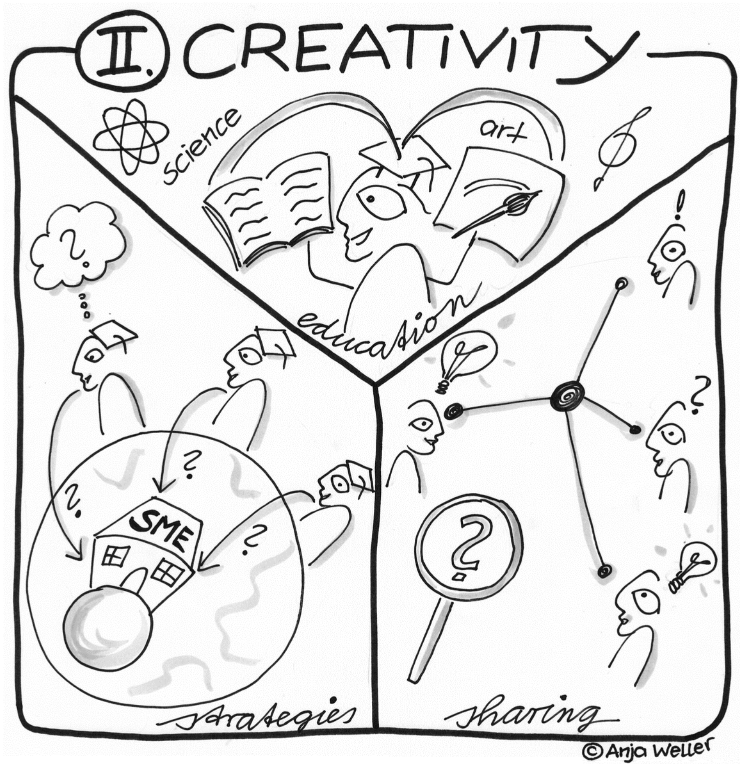
Chapter 2 contains the article, “The Imaginary Structure of the Fourth Industrial Revolution,” which was written by Dr. Thomas Michaud (France). The chapter focuses on how science fiction is increasingly involved in innovation processes in technological sectors. The imaginary, through design fiction, stimulates the creativity of engineers and innovators who work to create a better world through technoscience. Dr. Michaud talks about ‘imaginnovation’, a synthesis of the terms ‘imagination’ and ‘innovation’, which will guide decision-making in the Fourth Industrial Revolution and beyond. Science fiction is thus becoming an integral part of collective psychology and is considered an essential element of contemporary technical imagination.

Chapter 3, written by Julien Bucher and Dr. Anja Weller (Germany), is titled “From the Visual Turn to Turned Up Visuality: Modes of Interaction in the Digitalized Era and Ways to Utilize Them.” This chapter explains how the humanities and social sciences discovered the new field of visual research in the 1990s. This field centres on ‘turns’ such as the imagic turn, the pictorial turn, the iconic turn and the visualistic turn. These ‘turns’ emphasize the importance of visuality (or the visual mode) which has shaped the direction of research. Today, almost 30 years later, the individuals are heavily influenced by the digitalization of technologies and the globalization of material and immaterial goods. These goods – products, ideas and imaginations – rely on certain ways of visual presentation, images and visual media in general. Visual-based alternatives to commonly used methods such as interviews or surveys are discussed, finishing off with a description of the creative interview, a qualitative instrument used to gain and explicate information and imaginations based on sketches and drawings made by respondents.

SECTION 2: CREATIVITY IN THE FOURTH INDUSTRIAL REVOLUTION

“Creativity is a currency in 4th industrial revolution.”- The SA Art Times Network

Figure 2.



This section consists of six chapters with perspectives from Germany, South Africa and the Ukraine.

Chapter 4, titled "Is an Artist a Better Scientist? An Empirical Analysis on the Impact that Artistic Activity has on a Scientist's Achievement," was written by Rebecca Frenz, Julien Bucher and Anja Herrmann-Fankhänel (Germany). This chapter takes a close look at three studies by Root-Bernstein, seeking to confirm his findings by conducting interviews with scientists who have an artistic avocation. The results show that art offers an escape for scientists to reorganize their thoughts. If scientists combine the two worlds of art and science, their scientific work directly benefits from their artistic pursuits.

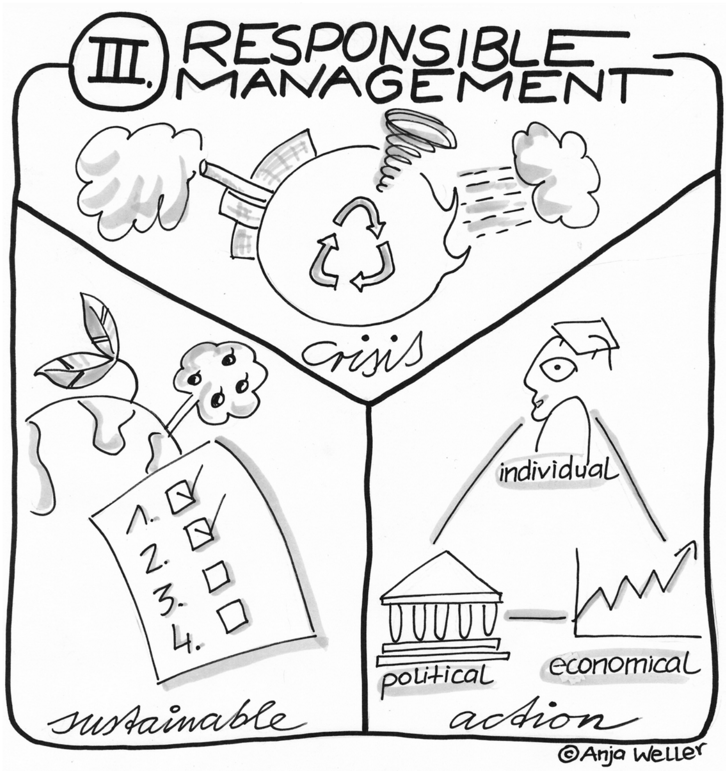
Chapter 5, written by Prof. Ziska Fields, is titled "Cognitive Skills Development at Higher Educational Level in the Fourth Industrial Revolution: A Case for Creativity." Prof. Fields explains that to compete in the Fourth Industrial Revolution, highly developed cognitive skills are critical. The chapter stresses that higher education institutions need to place greater emphasis on cognitive skills development to meet the demands of the future workplace. Creativity is especially important in this regard. The chapter describes two ways of assessing creativity and three techniques for developing creativity for higher education in the Fourth Industrial Revolution.

Chapter 6 was written by Dr. Justine Walter (Germany) and is titled "SMEs in the 4th Industrial Revolution: Creative Tools to Attract Talent and Shape the Future of Work." Dr Walter states that the Fourth Industrial Revolution is characterized by demographic developments that will provoke fundamental changes in the labour markets of many industrialised nations. This situation will especially affect Small and Medium-sized Enterprises (SMEs) in rural regions, with rapidly increasing numbers of retirees and an equally rapidly shrinking population of young people. If these companies want to maintain their levels of production in the Fourth Industrial Revolution, they will need to pursue new creative strategies to attract the best talent. All of this is true for Saxony, a highly industrialised German region with a large percentage of SMEs. The region has been hit hard by declining birth rates and high levels of emigration. Taiwan in South East Asia faces similar challenges. At the same time, many well-educated members of the young generation in both regions feel disrespected, underpaid and without prospects.

Chapter 7, titled "Knowledge Sharing and Creation in Virtual Teams: An Integrated Framework Based on Distributed Cognition Theory and Transactive Memory Systems," was written by Dr. Evi Kneisel (Germany). The chapter takes a holistic look at social, technical and individual aspects of knowledge sharing and generation in virtual environments. The chapter proposes a socio-technical framework based on distributed cognition theory and transactive memory systems. According to Dr. Kniesel, in combination, these well-established social theories provide theoretical foundations for describing and understanding how groups of individuals organize shared activities and interact with technology to store, retrieve and use individual knowledge for joint problem-solving and innovation.

Chapter 8, written by Dr. Deonie Francesca Botha (South Africa), is titled "Knowledge Management and the Digital Native Enterprise." Dr. Botha affirms that technology will change the way people work and will affect the operating model of organizations. Digital transformation will make work processes almost unrecognizable. In an age of rapidly evolving technologies, business models, demographics and even workplace attitudes will all shift concurrently. Change is thus not only constant but also exponential in its pace and scope. Dr. Botha states that knowledge management strategies support business processes in organizations. She uses case studies to show how knowledge management and the skillfulness of knowledge managers is important in the digital native enterprise.

Figure 3.



SECTION 3: RESPONSIBLE MANAGEMENT IN THE FOURTH INDUSTRIAL REVOLUTION

"The forces of the Fourth Industrial Revolution demand new forms of governance to safeguard the public good. Whether it will improve the human condition will depend on whether corporate, local, national, and international governance can adapt in time."- Klaus Schwab

This section consists of two chapters with perspectives from Germany.

Chapter 9, written by Prof. York Ulrich Kautt (Germany) is titled "Ecological Crisis, Sociality, and Digital (Self-)Management." This chapter focuses on the ecological crisis which is one of the most pressing problems of the present. Prof. Kautt discusses the importance of individual action for the ecological transformation of society and stresses that self-management is indispensable for such a transformation. Social reasons that prevent the development and implementation of new, pro-environmental types of practice are described in the chapter and recommendations are made for a (yet to be developed) creative form of self-management.

Chapter 10 is titled "Through Harmonization of National Technical Regulations to Promote More Sustainability in Engineering Businesses: How to Stay Compliant, Efficient, and Sustainable in International Engineering Businesses." The chapter was written by Dr. Julia Krause (Germany) who provides readers with insights into the complexity of engineering, delivering and constructing industrial plants while working in different countries. She explains that with different economic, social and environmental requirements on the one hand, coupled with challenges caused by globalization, digitalization and worldwide climate change on the other, it is vital to find ways for more sustainable project management and business models. This, according to Dr Krause, will inspire global players to consider sustainability development goals. Becoming an innovator will drive suppliers, clients and other stakeholders. The first step towards sustainable engineering processes in the globalized world is the harmonization of technical regulations worldwide.

In conclusion, the editors believe that the topics included in this book, contributed by authors from around the globe, will spur novel ideas, concepts and approaches to enrich the ongoing discussion on the importance of imagination, creativity and responsible management in the Fourth Industrial Revolution and beyond. They hope that this book will help future managers, students and academics to understand the importance of continuously developing their cognitive skills and to remain responsible and accountable in the new digital era which lies ahead.

Ziska Fields

Julien Bucher

Anja Weller

REFERENCES

Al-Montser, S. (2017). *Education in the 4IR*. In focus. Retrieved May 2, 2019 from https://infocus.wief.org/education-in-the-4ir/

De Haas, T. (2014, June 18). *The importance of Imagination* [About my brain]. Retrieved May 2, 2019 from https://blog.aboutmybrain.com/the-importance-of-imagination

Hoffmann, O., Cropley, D., Cropley, A., Nguyen, L., & Swatman, P. (2014). Creativity, requirements and perspectives. *AJIS. Australasian Journal of Information Systems*, *13*(1), 1–18.

Marr, B. (2018). The 4th Industrial Revolution Is Here - Are You Ready? *Forbes*. Retrieved May 2, 2019 from https://www.forbes.com/sites/bernardmarr/2018/08/13/the-4th-industrial-revolution-is-here-are-you-ready/#745335b1628b

Rodny-Gumede, Y. (2019). *South Africa needs to think differently and embrace 4IR.* Retrieved June 22, 2019 from https://mg.co.za/article/2019-03-08-00-south-africa-needs-to-think-differently-and-embrace-4ir

Rush, J. (2018). *Understanding your Creative Engine — The 8 Types of Imagination*. Retrieved June 22, 2019 from https://writingcooperative.com/understanding-your-creative-engine-the-8-types-of-imagination-5265ebdae79f

Schwab, K. (2019). *Our global system has spun out of control. Here's how to rebalance it.* World Economic Forum. Retrieved June 22, 2019 from https://www.weforum.org/agenda/2019/02/how-to-rebalance-our-global-system/

Vandervelde, W. (2018). *When the box is the limit: Drive your creativity with constraints*. Amsterdam: BIS Publishers.

Wilhelm, K. (2013). *Return on stability: How business can increase profitability and address climate change in an uncertain economy*. Upper Saddle River, NJ: Pearson Education, Inc.

World Economic Forum. (2017). *Accelerating Workforce Reskilling for the Fourth Industrial Revolution: An Agenda for Leaders to Shape the Future of Education, Gender and Work*. White paper. Retrieved June 22, 2019 from http://www3.weforum.org/docs/WEF_EGW_White_Paper_ Reskilling.pdf

Acknowledgment

The editors would like to thank the chapter contributors, reviewers and the IGI Global team for all their hard work, commitment and support during the publication process. We value your collaboration and professionalism.

Ziska Fields
University of Johannesburg, South Africa

Julien Bucher
Chemnitz University of Technology, Germany

Anja Weller
Saxon State Ministry of Education and Cultural Affairs, Germany

Section 1

Imagination in the Fourth Industrial Revolution

Chapter 1
On the Principles of Imagination and Creativity:
Philosophy, Neuroscience, and the 4IR

Rajashree Chaurasia
https://orcid.org/0000-0001-5722-3668
Directorate of Training and Technical Education, India

ABSTRACT

Human beings are the only mammals to be able to utilize high-level cognitive functions to build knowledge, innovate, and communicate their complex ideas. Imagination, creativity, and innovation are interlinked in the sense that one leads to the other. This chapter details the concepts of imagery, imagination, and creativity and their inter-relationships in the first section. Next, the author discusses the historical perspectives of imagination pertaining to the accounts of famous philosophers and psychologists like Aristotle, Kant, Hume, Descartes, Sartre, Husserl, and Wittgenstein. Section 3 and 4 present the neuro-biological correlates of imagination and creativity, respectively. Brain regions, neuronal circuits, genetic basis, as well as the evolutionary perspective of imagination and creativity are elicited in these sections. Finally, creativity and innovation are explored as to how they will contribute to knowledge build-up and advances in science, engineering, and business in the fourth industrial revolution and the imagination age.

DOI: 10.4018/978-1-5225-9188-7.ch001

INTRODUCTION

Come with me and you'll be
In a world of pure imagination
Take a look and you'll see
Into your imagination
We'll begin with a spin
Trav'ling in the world of my creation
What we'll see will defy
Explanation
(Bricusse & Newley, 1971, track 5, verse 1)

The excerpt above has been taken from the 1971 movie *Willy Wonka and the Chocolate Factor*y. In the scene featuring this verse, Willy Wonka (played by Gene Wilder) sings this song, titled "Pure imagination", while introducing the golden ticket winners to the *Chocolate Room* of his chocolate factory. We see the extraordinary world Willy Wonka has created because of his imagination where there is a chocolate waterfall, a chocolate river, toadstools made of candy and cream, trees with candy and giant gummies as fruit, giant lollipops growing as if from the grass, etc.; a chocolate lovers' delight! Here is a fictional example of how pure imagination can give rise to fantastic creations. In real life too, there are numerous examples of such feats, be it in art, music, scientific discoveries and inventions, entertainment, engineering, medicine, architecture, construction, business, etc. In everyday life, everyone uses their faculties of imagination and creativity in dealing with everyday situations and making decisions, responding to novel changes in their environment, and the like.

Imagination, creativity and innovation are factors that contribute to an animal's intelligence and not all species share these traits. Imagination and creativity are the high-level cognitive functions of the brain that make us human. Rudimentary imaginative and creative abilities have been shown to be present in bees, ants, birds, rats, and the great apes (see McNamara et al., 2007; Gould, 1990; Wehner & Menzel, 1990; Durier et al., 2003; Visalberghi & Fragaszy, 2001; Layman, 2010; Mitchell, 2012; Soler et al., 2014). However, human beings are the only mammals to be able to utilise these functions to build knowledge, innovate, discover, invent and communicate their complex ideas. Imagination and creativity are interlinked in the sense that one leads to the other. Innovation stems from creativity as has been reported by many scientists, researchers, entrepreneurs, inventors and geniuses. Thus, all these concepts are inter-related in one way or another. This chapter begins with the concepts of imagery, imagination and creativity and their relationships in the first section. Next, the author discusses the historical perspectives of imagination pertaining to the accounts of famous philosophers like Aristotle, Kant, Descartes and Wittgenstein. Section three and four present the neurobiological correlates of imagination and creativity, respectively. Brain regions, neuronal circuits, genetic basis as well as the evolutionary perspective of imagination and creativity are elicited here. Finally, creativity and innovation are explored as to how they will contribute to knowledge build-up and advances in science, engineering and business in the fourth industrial revolution and the imagination age.

IMAGERY, IMAGINATION AND CREATIVITY

Mark J. Polland (1996), in his doctoral dissertation, examined 44 accounts of experiencing imagery along with creative discoveries made by scientists, artists, musicians and writers. Among the 29 scientists' accounts he studied, were the ones of Albert Einstein, Isaac Newton, Stephen Hawking, Nikola Tesla and many more. This tells us that imagery and imagination are necessary ingredients of creative works of not only artists, musicians, writers and designers, but also of the creative inventors and scientific researchers. Let us first examine each concept and its meaning and then try to grasp their inter-relationships.

The Concept of Imagery

The Oxford English Dictionary defines imagery as a collection of visual images or a visual symbolism. The word "imagery" has its origins in Old French "*imagerie*" or "*imager*" meaning "make an image". Mental imagery is of many forms viz. visual, auditory, tactile, gustatory and olfactory (Polland, 1996). However, visual imagery and mental imagery are often used interchangeably, sometimes even referred to as simple visualization, representation or seeing with the mind's eye.

Visual imagery is a process of creating mental images that helps us to form memories and retain information for future recall. For example, while reading fiction, painting a mental picture in the mind of the description of a character's appearance and the scene helps us to appreciate the style of the author, as well as, aids in connecting pieces of seemingly unrelated information stored in memory as we visualize, by the process of recall. Sometimes, we do not even need to make a conscious effort to visualize something, in which case, mental imagery becomes involuntary. Visual imagery further enables us to think and reason about things that are not currently present in the visual field. This capability plays a significant part in numerous cognitive processes, like working memory, mental rotation, reasoning about future events, etc. (Kosslyn et al., 2001). The more vivid a mental picture formed in the brain, the more powerful is its significance in the performance of these cognitive faculties. For example, if someone is asked to remember a minute detail about a certain object or event that has been experienced in the past, like say, what colour a certain someone was wearing on a certain occasion, then most people report that in answering such a question, they form some type of a mental image of that event and inspect the scene created in the mind for that specific information. If a person's ability to visualize is very vivid, then that person may be able to recall such miniscule details easily and better than others whose capabilities of visualization are not as rich. Frequently, one might be able to discover properties in such an image that they were unaware of when experiencing those objects, known as emergent properties and experimental demonstrations of these properties were provided by Finke, Pinker, and Farah (1989). Oftentimes, people do not even realize that they know certain details of certain events as some of the processes of mental imagery are spontaneous in nature (Galton, 1880a, 1880b, 1880c, 1883; Faw, 1997, 2009). However, it is also true that not all thought process and reasoning is associated with visual mental imagery. We will discuss more about these issues in the coming subsections when we look at how imagery and imagination are related to each other.

The Concept of Imagination

"Imagination is everything. It is the preview of life's coming attractions."- Albert Einstein

Imagination can generally be defined as a faculty of the mind to be able to form novel ideas, images or concepts of objects that are not currently present to the senses. Its origins lie in Latin "*imaginari*" meaning "picture to oneself". A more scientifically relevant definition appears in (Agnati et al., 2013):

Imagination: the act or power of forming mental images of what is not actually present or has never been directly experienced. Notably, imagination not only has the potential to enrich the meaning of an experience and deepen understanding, by multiplying and expanding the perspectives from which a phenomenon can be considered, but it also allows anticipating the outcome of an action without actually performing it via a "simulation" process. At its peak, imagination is the very mental faculty underlying visionary and creative thought. In other words, imagination is not simply the organization, identification, and interpretation of sensory information in order to represent and understand the environment but rather a constructive process that builds on a repertoire of images, concepts, and autobiographical memories and leads to the creation (and continuous update) of a personal view of the world, which in turn provides the basis for interpreting future information. (Agnati et al., 2013)

Every human mind is unique in terms of the inner world formed by the neurobiological substrates of consciousness. Each human brain in exceptional in the interconnections of neurons (a brain cell) and the neuronal circuits created thus, that give rise to neuronal maps in the complex human brain. These aspects will be detailed in the subsequent sections. The ability to generate novel ideas, images, concepts is exclusive to the human species. Only rudimentary mental imagery and imagination has been shown to be present in other species of the animal kingdom (see McNamara et al., 2007; Gould, 1990; Wehner & Menzel, 1990; Durier et al., 2003; Visalberghi & Fragaszy, 2001; Layman, 2010; Mitchell, 2012; Soler et al., 2014). Humans have the power to be able to look at a phenomenon from various perspectives, analyse a situation from multiple angles, think from another person's viewpoint, simulate possible future scenarios before taking a decision on how to act in certain situations and predict the outcome of a future scenario based on the analysis of all these aspects. Imagination plays a significant role in all these high-level cognitive functions. The power of the imagination has been given much emphasis in the 2006 spiritual best-seller by Rhonda Byrne – The Secret (Byrne, 2006). In her book, Byrne describes the role of imagination in creation and invention as:

The only way anything has ever been invented or created is because one person saw a picture in his mind. He saw it clearly, and by holding that picture of the end result in his mind, all the forces of the Universe brought his invention into the world, through him. (Byrne, 2006)

Byrne further talks about the Law of Attraction in her book, advising us to imagine whatever it is that we want to attract in life, be it money, fame, power, or anything that we truly desire. She points out that we must focus on imagining that the things we wish for are already adequate in our lives. In doing so, we attract more positivity and thus, greater quantity of what is desired. Let us now examine the process of imagination to understand just how we can create representations of objects and events in the real world and use these to manipulate and create new representations.

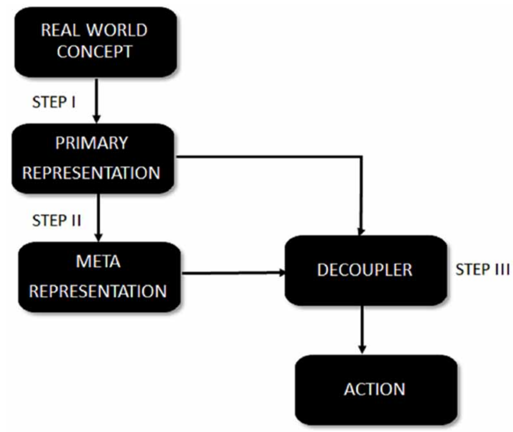
The Process of Imagination

Alan M. Leslie (1987), presented a theoretical analysis of the representational mechanisms underlying the ability to imagine. More specifically, he studied the ability of pretend-play or pretense, seen more often in children than in adults. Pretense has always intrigued cognitive psychologists as a bizarre capability wherein, the veridicality of real objects and events is intentionally twisted. For example, when a child pretends that a certain teacup contains tea, when it actually does not, the child has formed an internal representation of an object from the real world and then distorted that representation to form new interpretations. From the definition of imagination discussed in the previous section, it then becomes clear that pretense is a form of imagination.

According to Leslie (1987), this process involves three steps (see Figure 1). First and foremost, we have what he called '*primary representations'* or the basic capability to be able to represent aspects of the real world in a veridical or truthful way. Primary representations have direct relations to the objects of the outside world which forms knowledge of objects and their meanings. The second step is, then, to create a clone of primary representation, termed '*meta-representation*' (Leslie, 1987). Meta-representation is removed or decoupled from the truth relations that the primary representation bears to the actual objects in the real world. However, in doing so, the primary representation has not lost its meaning; it still refers to the same concept of the real world that it represented when it was first formed in the mind. For instance, the primary representation of the concept 'banana' has not lost its meaning when its meta-representation is used in pretense to mean something else, like, say a telephone. The purpose of a meta-representation is to permit the brain to manipulate reality in an infinite number of ways, and to explore many possibilities. The third step is to distort or change the meta-representation to create new representations using a *decoupler*. For example, in the case of pretending a banana as a telephone, the primary representation of the concept of the banana is first converted as a copy, to a secondary representation or a meta-representation of the concept of the banana and then, this meta-representation is altered and fused with the meta-representation of the concept of the telephone. In doing so, the primary representations of banana and telephone are not touched upon and therefore, the meanings of the concepts banana and telephone remain unaltered. Had this not been the case, then the realities of the concepts banana and telephone would have been distorted as well. If the primary representations are altered, then the direct relationships of the objects they represent in the real world would also be altered. This would lead to utter confusion and chaos in the mind. However, this is not the case as children are able to distinguish between their primary and secondary representations easily. After using a banana as a telephone in a pretend play scenario, they do not start eating a telephone thinking it is a banana, nor do they form the general knowledge that a banana can be used to communicate with people over long distances.

The 'decoupler' given by Leslie (1987) consists of three sub-steps (Figure 2). Let us examine once again the case of pretending that a banana is a telephone. The primary representation of the concept of banana is converted to a meta-representation of the banana by the *expression raiser* component. The *manipulator* alters the meta-representation of the banana by accessing the primary representation of the concept of telephone to merge the two inputs and generate the pretend representation "This banana is a telephone". Finally, the *interpreter* component acts on the pretend

Figure 1. Imagination Process

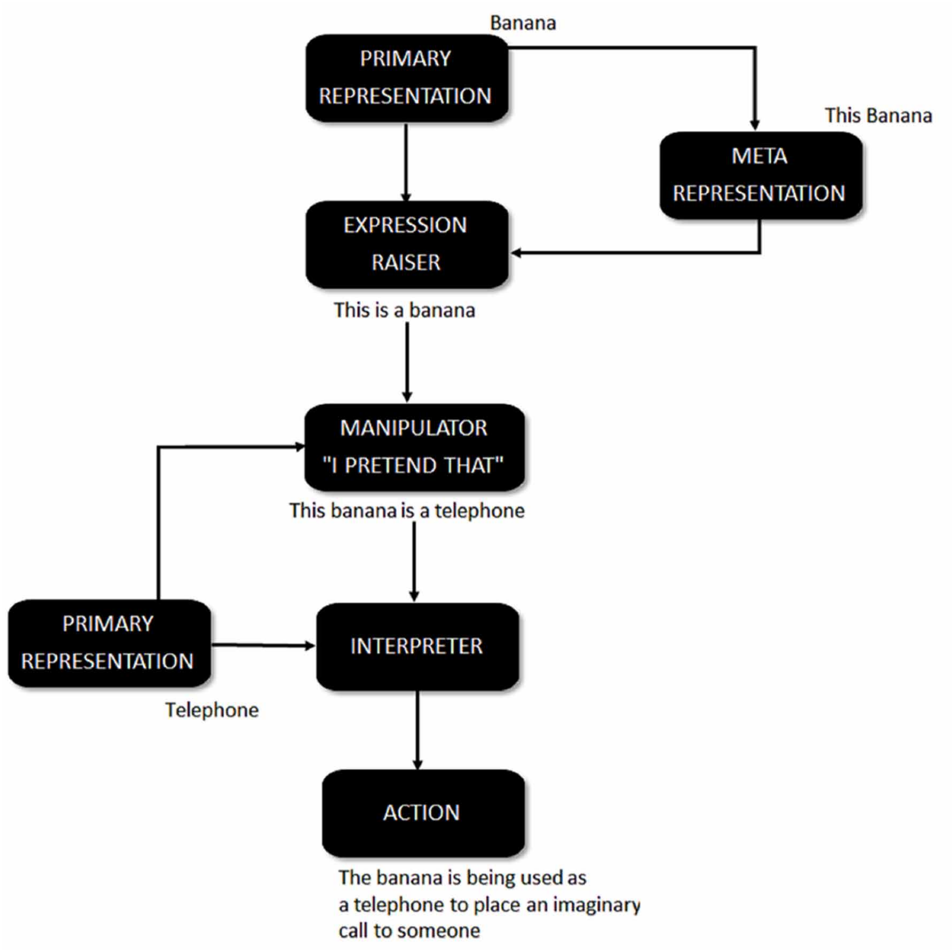


representation and relates it to the current perceptual representation by accessing the primary representation of telephone. The end result is that the banana is used in making an imaginary call to a person and pretending to have an imaginary conversation. The neuroanatomical substrates of this process will be discussed in the subsequent sections. Let us turn our attention to the creative processes of the brain.

The Concept of Creativity

The Oxford English Dictionary defines creativity as "the use of imagination or original ideas to create something; inventiveness". The Cambridge English dictionary defines creativity as "the ability to produce original and unusual ideas, or to make something new or imaginative". However, this definition is not significant as it is not a complete account of creativity. Merely conjuring something by merging two different concepts into one may not be significant in a wider context. For example, merging the concepts of an eagle and lion to create a lion with the head of an eagle is not creativity unless it has wider implications. Thus, creativity not only requires the use of original ideas, but also requires those ideas to have some value. However, even this may not completely cover the essence of creativity because a valuable creation can also be created by pure chance or via mechanical procedures. According to Berys Gaut (2003), creativity involves a possible third paradigm, namely, that of flair. He stresses that a novel idea that has value is produced only with flair. Therefore, creativity involves essentially three concepts – novelty, value and flair.

Figure 2. Decoupler model (both based on Leslie, 1987)



Combinational, Exploratory and Transformative Creativity

Margaret Boden discusses three types of creativity, categorized on the basis of the psychological means involved in generating the novel idea, viz. combinational, exploratory and transformational creativity (Boden, 2004). Combinational creativity is the type in which, the process of recombination of familiar ideas generates the novel idea. This is consistent with the recombinant theory of creativity postulated by David Novitz (1999), an extract from which is given below:

Allowing that the term 'object' may include sensations and qualities as well as physical objects, my claim is that all creative acts require

1) The intentional or chance recombination of such ideas, techniques, or objects – where this recombination is subsequently deliberately used or deployed
2) In ways that result in something that is (or would have been) surprising to – hence, not predicted by – a given population, and
3) In ways that are intended to be, and are potentially, of real value to some people.
4) These three conditions are each necessary and jointly sufficient for creativity. (Novitz, 1999)

Hence, Boden agrees with Novitz that creativity entails an element of surprise as the third component as opposed to Gaut's 'flair'. Exploratory creativity generates new ideas by the exploration of a conceptual space which were deemed impossible prior to exploration. A conceptual space is an existing style or culture, like, the different styles of painting viz. abstract, contemporary, expressionist, classical, neoclassical, etc., theories in physics, styles of cooking, etc. To explore the conceptual space implies trying out different things within that conceptual space to create something new and valuable. Transformative creativity involves the transformation of the existing conceptual space such that the new ideas that are generated as a result, seem quite impossible as they were not previously conceivable in the unchanged conceptual space. This type of creativity occasions the greatest amount of surprise.

Active and Passive Creativity

Gaut (2003) describes two types of creativity – active and passive. Passive creativity occurs when the creator is unaware of the creative process that led to the creative feat, such as in dreaming or when the solution suddenly 'pops' into the mind. Active creativity, on the other hand, occurs when the creator consciously explores alternatives, experiments with them, re-evaluates and refines them, and then reaches a solution.

The Four C Model of Creativity

Kaufmann and Beghetto (2009) gave four categories of creativity in their 'Four C' model, viz. Big-C, Pro-C, little-c and mini-c. It is common knowledge that each person is creative. Creativity is not a gift from God that is bestowed to only a few. However, people differ in their strength or levels of creativity. The lowest level of creativity in the 4C model is the mini-c level. According to the model, every person begins at this level, but only a small percentage of people may reach the highest level, i.e. Big-C.

Mini-c is defined as the novel and personally meaningful interpretation of experiences, actions, and events (Beghetto & Kaufman, 2007). Mini-c happens when a person establishes "flexibility, intelligence and novelty" in their thinking (Craft, 2005). It is usually applied to children's creativity, but it can be applied to adults as well. Mini-c creativity is exhibited for example, by learners who devise new ways to solve a problem, to remember, to understand a piece of information, etc.

Little-c creativity is defined as 'acting with flexibility, intelligence and novelty in the everyday' (Craft, 2005) which results in creating ideas that have 'originality and meaningfulness' (Richards, 2007). Little-c creativity involves practice. It is seen most at the workplace of an individual, i.e. in the professional front. For example, creativity in photography, art, sculpture, teaching, etc. are instances of little-c creativity. In this digital age, it is very easy to share your creative feats with others via videos such as websites like YouTube, Facebook and Instagram.

Pro-C creativity involves a lot of hard-work and experience to develop, usually taking a long time (around 10 years). It is also known as professional expertise with world class expert level status, reaching the stage of high eminence. For example, children showing the talent for music, if trained throughout their childhood and well into adolescence and adulthood may achieve pro-c creativity in the field of music and top the charts by their gripping songs.

Big-C creativity often requires a degree of time, sometimes taking decades to truly ascertain the actual impact. Many a time, the significance of their creative contribution is not well received around the time of their manifestation and their work remains forgotten for a long time before someone realizes the implications of their creation, sometimes even after their death. Big-c creativity is often considered as the marks of a genius. Examples of such geniuses are Charles Darwin and his theory of evolution, Leonardo da Vinci's Mona Lisa, Bach's "Mass in B Minor", etc.

The Creative Process

There are many models of creativity that detail the creative process. The four-stage model of creativity, formulated by Wallas (1926), is considered the basic model around which, most of the other models are based. In this section, we will discuss briefly Wallas's model and the geneplore model given by Finke, Ward, and Smith (1992).

The Basic Four-Stage Model

Wallas (1926) formalized the basic model of the creative process that consists of four steps, viz. *preparation, incubation, illumination and verification*. In the first phase, major tasks involved are primary analysis of the problem and its definition. Preparation involves conscious work and draws on one's education, analytical skills, and problem-relevant knowledge (Lubart, 2001). Next follows the phase of incubation. It is during this phase that the conscious and subconscious are working on an idea, making new connections, filtering out superfluous thoughts, and grabbing for other, more significant ideas. Incubation does not involve conscious effort on the problem defined in the first phase. The mind may be relaxing or thinking about other problems or even just daydreaming. During illumination, when the promising idea breaks through to conscious awareness, it is embodied by a 'flash', a sudden enlightenment, a 'eureka' moment (Lubart, 2001). Illumination can be difficult to achieve since the mind is easily disrupted by even the slightest distractions, causing the eureka moment to suddenly vanish from consciousness altogether. The result is a lot of frustration, as it very difficult to get back to the idea by forcing the brain to bring it forth from the depths of the subconscious. Wallas insisted that oftentimes, this phase was immediately preceded by an intuitive sensation of the inception of the desired idea. The final phase, verification, involves developing the idea, refining it to resolve any issues that may come to mind, evaluating its feasibility, reworking on the idea if, during evaluation and refinement, it is found that the idea thus generated, has some faults. This could cause the individual to cycle back to any of the previously mentioned phases. Many researchers support this model and its variants (see Rossman, 1931; Patrick, 1935, 1937, 1938; Hadamard, 1945; Osborn, 1953; Taylor, 1959; Taylor, Austin, & Sutton, 1974; Stein, 1974; Busse & Mansfield, 1980; Cagle, 1985; Ochse, 1990; Amabile, 1996; Goswami, 1996). Osborn's (1953, Father of brainstorming) seven-step creativity, based on Wallas's model, starts with orientation i.e. chalking up the problem, followed by preparation, data analysis, ideation (wherein brainstorming rules are used to elicit all the possible alternatives), incubation, synthesis of ideas and finally, evaluation of resulting ideas. There are many critiques of the basic model (see Eindhoven & Vinacke, 1952; Vinacke, 1952; Guilford, 1950, 1967; Ghiselin, 1956, 1963, 1985; Weisberg, 1986; Bailin, 1988) as well, who point out that creativity is an integrated approach and the four stages themselves are composed of multiple subprocesses (see Lubart, 2001).

The Geneplore Model

The geneplore model of creativity proposed by Finke, Ward, and Smith (1992), distinguishes between two general types of cognitive processes, viz. *generative and exploratory*. The generative processes are utilized in the construction of loosely formulated ideas called pre-inventive structures. The exploratory processes are used in the examination, interpretation, and testing of these structures. This is a cyclic process of refinement of pre-inventive structures that reiterates till they achieve their final form. Constraints can be imposed on these final products such as their components, functions or categories. Some examples of generative processes are mental synthesis (Finke, 1990; Thompson & Klatzky, 1978), association (Mednick, 1962), memory retrieval (Smith, 1995a, 1995b), etc. Examples of exploratory processes include attribute search (Hampton, 1987), hypothesis testing (Neisser, 1967; Newell & Simon, 1972), and finding limitations (Levine, 1987).

Imagery and Imagination

Alan White (1990) argued that imagination neither implies imagery nor is imagery implied by imagination. Imagination does not imply imagery since there are many instances of imagination that cannot be visualized in tangible terms, and therefore, do not pertain to imagery. Imagery as discussed previously, implies the existence of a visual image. However, in order to imagine being hurt, humiliated, insulted, etc., tangible visual images of hurt, humiliation and insult don't exist. Similarly, White argues that we cannot have images of 'some', 'all', 'none', 'here', 'now', 'there', etc. It is easy to imagine that someone is in pain; however, it is very difficult to have an imagery of 'pain'. Thus, imagery is confined to what can be copied or picturised, but imagination is not. Imagery does not imply imagination either. Imagery occurs while dreaming, recall, wishful thinking, etc. In none of these cases we are imagining anything. Therefore, not all instances of imagery contribute to imagination. White goes on to say that imagery has certain characteristics that are absent in imagination and itself lacks certain other characteristics which are present in imagination. An extract from his account is given below:

One's imagery often presents one with unexpected features. It can come and go independently of one. Having imagery, but not imagining, is an experience. Imagination, on the other hand, is very much under one's voluntary control, even though often one can't help imagining that, for instance, one is being persecuted or that one has heard a noise. What one imagines is what one conjectures, not what is present to one. […] It (imagery) is particular and determinate, whereas imagination can be general and indeterminate. […] Even more importantly, imagery does not express anything, whereas imagination does. (White, 1990)

While Ryle (1949) and Walton (1990) support White's claim to an extent, Currie and Ravenscroft (2002) strongly criticise his theories. They support the views of Aristotle, Descartes, Hume and Kant in saying that imagery plays an important role in imagination. Currie and Ravenscroft pointed out that there are cases of imagination too that are involuntary. Thus, there seems to be no basis for claiming that imagination and imagery have essentially different properties. They also claimed that one can be surprised by what one imagines and that imagination and imagery both can be indeterminate. In the imagery of a leopard, for example, that image cannot be distinguished from a second imagery of a leopard with a few lesser spots than the first. Gregory (2016) supports the view that imagery plays an important part in imagination by using the term ‘imagistic imagining’ for episodes of imagination featuring mental imagery. He states that, “One important way in which mental imagery and the imagination seem to be connected is thus as follows: what we imagine – the ‘content’ of our imaginings – is often significantly shaped by what is shown in mental images”. He further defines a ‘purely imagistic imagining’ as one in which the content of the imagining is completely fixed by the content of the accompanying mental imagery. However, not all imaginings are purely imagistic imaginings and there may be some non-imagistic imaginings as well. Some philosophers believe that imaginings can occur without accompanying mental images while some others believe otherwise. The relationship between mental imagery and imagination is consequently particularly intricate and apt for further enquiry.

Does Creativity Stem from Imagination?

Gaut (2003) discusses at length, how the imagination contributes to creativity through two models, viz. the display and search model. In the display model, Gaut suggests that imagination plays only a marginal role in passive creativity (see section ‘The Creative Process’). Gaut establishes here, that there are many cases of imagination that do not contribute to genuine creativity. In some cases, creativity operates through the unconscious to engender the idea which is then presented via imagination. He gives two examples to support this argument, first, Kekulé’s discovery of the benzene ring structure and second, Russell’s solving of difficult problems. In both cases, the creative feat was achieved through the act of dreaming. Kekulé was inspired by the image of a snake eating its own tail that led to the discovery of the closed ring structure of benzene. Russell came upon the solution of difficult problems when he was not dwelling on them, i.e. when during the incubation phase of the creative process (see section ‘The Creative Process’). Gaut’s display model centres around passive creativity and thus, which fails to capture the inherent role of imagination in creativity.

The search model involves active creativity (see section ‘The Creative Process’) in which case, the imagination forms a core part of the creative process. It further contributes to the argument that imagination is implied by creativity. Gaut declares that imagination is used for the exploration of the various possibilities in the search model and therefore, imagination acts as a ‘vehicle’ or ‘medium’ for creativity but not as the source of creativity. Creativity is demonstrated in how the imaginative faculty is used which further demands experience, knowledge of the field, expertise, skill and talent. In doing so, imaginative faculties exhibit freedom insomuch as, we can try out different possibilities in our minds without essentially acting on or committing to the veracity or falsity of any of them.

Gaut also talks about how Kant applied the notion of imagination to the generation of creative aesthetic ideas with metaphors. Gaut believes that metaphor-making (discussed in subsequent sections) is a paradigm as well as an instance of creative imagination since it shows flair, novelty and exhibits value of aptness – the three components of creativity. From Gaut's account, much of creativity involves imagination in some way or another. However, not all imaginative processes result in creativity. In a nutshell, it will suffice to say that though creativity implies imagination, imagination does not imply creativity.

HISTORICAL PERSPECTIVES OF IMAGINATION

In the ancient civilizations of the world, myth and lore were exemplars of great intellectual power and imaginative vividness. Before writing became commonplace, oral myths and lore were the only ways to pass on knowledge. The eccentricity and richness of such myths helped to remember the past events better. Therefore, stories with outlandish events were woven around knowledge as a memorizing technique over generations, giving rise to the need to improvise and imagine. However, even with the advent of writing, the importance of imagination did not wane. Let us now briefly turn our attention to what distinguished philosophers thought about the imagination. Nevertheless, the critical discussions of these views as well as views in support of these conceptions are out of the scope of this book.

Aristotle's Phantasia

Aristotle (384 BC – 322 BC), in *De Anima 3.3* (Barnes, 1984), referred to the concept of the imagination as 'phantasia' and the associated images as 'phantasms'. Aristotle claimed that without phantasms, there can be no thought. He considered these images or phantasms as representations of external entities on the lines of primary representations and meta-representations as explained by Leslie (1987). He supported the role of imagination in thought, memory, dreaming, in action and in illusion, but distinguished it from perception and belief. According to him then, imagination is a faculty in humans and most other animals which produces, stores, and recalls the images used in a variety of cognitive activities, including those which motivate and guide action. However, he made it clear that recollection or 'anamnesis' and rational thinking are capacities exclusive to humans. Rational thinking employs the conceptualization of sensory objects through symbolic representations or universals or meta-representations as Leslie points out (Leslie, 1987) – therefore, phantasia. Further, phantasia provides the necessary content for movement owing to its ability to bring forth sensory content even in the absence of appropriate sensory stimuli.

As an example, consider a bird that travels to a bird-feeder when a feeder occurs in sight, even though it may not be able to see the food in the feeder.

René Descartes

Descartes (1596-1650) was a purely rationalist philosopher and supported the ideas of Aristotle regarding the impossibility of thought without some form of imagination. Descartes used the faculties of the imagination in his mathematical and scientific research. Sepper (2016) gives a wholesome account of Descartes's thinking. Sepper declares that Descartes presented imagination as a dynamic power for grasping, projecting and synthesizing the mathematical proportional relations, especially when studying the musical relations in his treatise *Compendium of Music* (1618). In his Sixth Meditation, Descartes distinguishes between imagination and understanding by saying that imagination requires a 'peculiar effort of mind'. He also differentiates between ideas and images when he remarks that 'whatever we conceive without an image is an idea of the pure mind, and whatever we conceive with an image is an idea of the imagination'. Sepper points out that 'ingenium' or innate intelligence is seen as the power of working on ideas of the imagination, either forming new ones or examining existing ones. In using our imaginative abilities for problem solving, we discover new relationships between familiar concepts. This, Descartes showed using diagrammatic exemplars of mathematical proportionality.

Immanuel Kant

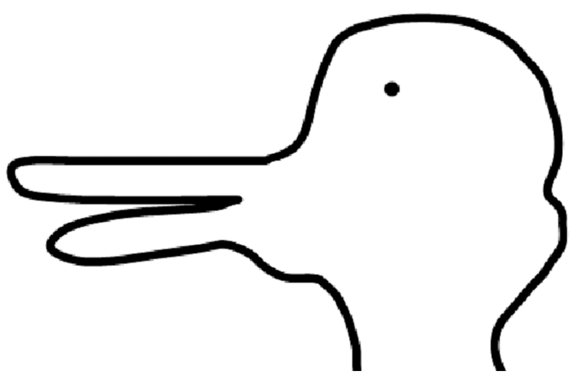
Kant (1724-1804), in his *Critique of Pure Reason*, talks about two types of imagination – the productive and the reproductive. Kant is considered partly empiricist and partly rationalist insomuch as he believed that knowledge requires both, sense experiences (passive) as well as rational thinking (active). Matherne (2016), in her account of Kantian philosophy of the imagination, suggests that Kant sees imagination as a faculty responsible for intuitive, sensible representations of objects that are not directly present to us. Productive or transcendental imagination, then, makes experience possible, and reproductive imagination produces presentations that are derived from past experiences (empirical).

Ludwig Wittgenstein

Wittgenstein's (1879-1951) *Philosophical Investigations* (1958) discusses the nature and role of images as the concept of 'seeing as'. According to him, to understand the nature and process of imagination, we need to first understand how the word 'imagination' is used. He further points out that the mental picture of an object is determined by the description someone gives of that mental picture. For example, what someone forms a mental picture of an object's redness can only be determined by how one describes that mental image. Wittgenstein also distinguishes between two uses of the word 'see'. The first one, he says, is simply the perception of the object as it appears before us. The second, interpreted as 'seeing-as', is a relationship drawn between what is perceived or seen, and noticing its similarity with something else called as 'noticing an aspect'. In other words, the object seen in the first sense of the word does not change in appearance in reality, however, it is being looked at differently or from a different aspect, as being similar in appearance to something else. This is essentially, forming a new perception of the perceived object. Wittgenstein explains this phenomenon with many examples, the most famous of them being that of the duck-rabbit (Figure 3).

Let us say, for instance, that someone perceives the duck-rabbit as a duck. This corresponds to the first use of the word 'see'. However, upon continually looking at the picture, a new interpretation may arise in the mind, that of perceiving the image as a picture that looks like a rabbit (if the mouth of the duck is perceived as the ears of a rabbit). The picture has not changed, however, our interpretation of it has. In this respect, the second interpretation of 'seeing-as' applies. Further, to view the picture as a duck or rabbit, one must first have seen a picture of a duck or rabbit in the past, to relate to this image as either one of them. However, only an imagined picture of some duck or rabbit may suffice for this purpose. Therefore, according to Wittgenstein, imagination is the core process of 'seeing-as'.

Figure 3. The Duck-Rabbit (Based on Wittgenstein, 1958)



THE NEUROBIOLOGICAL CORRELATES OF IMAGINATION

Simon Baron-Cohen (2006), in his essay on the biology of imagination, stated that the content of imagination is determined largely by culture than biology, however, the capacity to imagine is determined more by biology. To elaborate, culture shapes the knowledge of a human society and further, affects the social behaviour of the societal group. Since we have already established from previous sections, that, for someone to be able to imagine something, knowledge of what is being imagined is vital and perception of the initiating phenomenon is needed to model and manipulate the imagination, it follows that culture is responsible for the content of the imagination. However, the capacity to imagine is another notion altogether. Imagination stems from the brain of the human body that contains neural cells or neurons. The capacity to imagine something, then, implies the ability of these neurons to communicate with other neurons in ways that creates imaginative experiences. We shall elaborate on these aspects in this section.

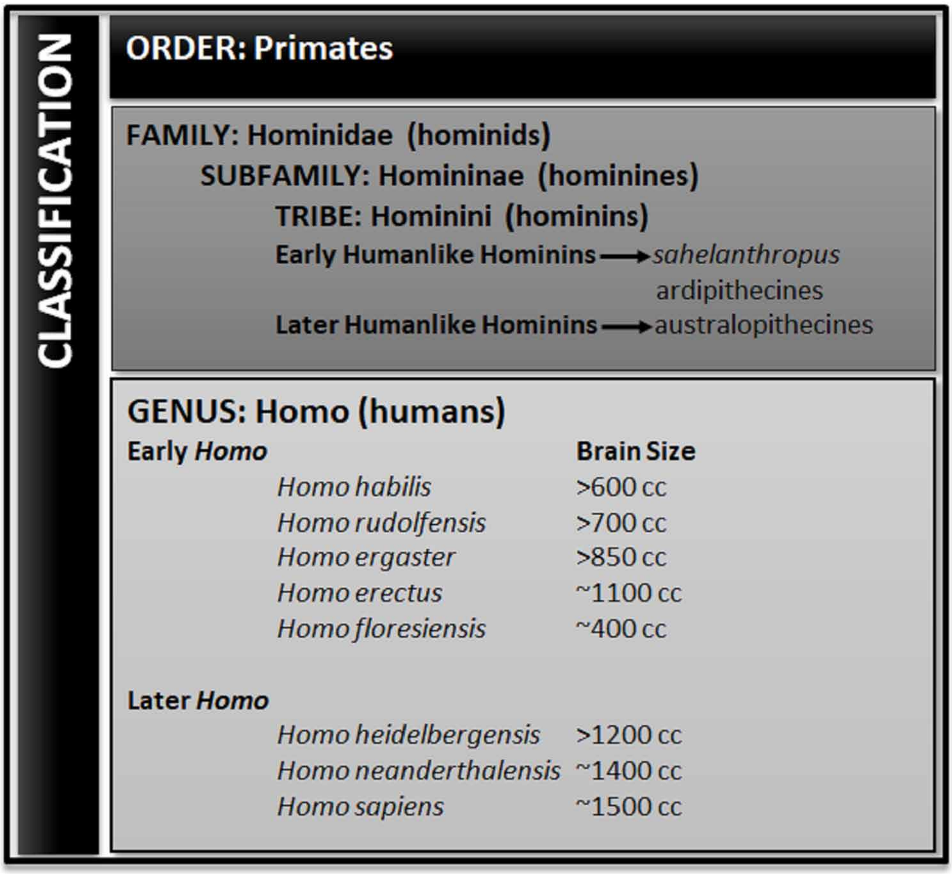
Evolutionary Perspective of Imagination

According to biology, the mammalian order *Primates* includes prosimians, monkeys, apes and humans (Mader & Windelspecht, 2016). Evolutionary theories state that *Hominins*, i.e. humans and the species closely related to human beings, evolved around five million years ago. Recent genomic data reveals that humans are closely related to chimpanzees, with a difference in their genomic base sequences of only 1.5% (Mader & Windelspecht, 2016). For this reason, the chimpanzees have been taxonomically reclassified as included in the same sub-family as humans – *Homininae*. The evolutionary trend among primates has been towards a bigger and more complex brain. Genetic evidence advocates that genes responsible for brain complexity and its increase in size, may have been affected most, by gaps existing in the chimpanzee and human genome, which accounts for some of the 1.5% difference.

Steven Mithen (2008) expounds on a seven-step evolutionary hypothesis (see Figure 5) for imagination in *Homo sapiens* (humans). The *first* step addresses the evolution of a theory of mind - the principle of awareness of belief and thoughts in others that may be different from one's own thoughts and beliefs, which is further related to imagination. Without imagination, which is essential to forming complex social interactions, it is not possible to gauge the perspective of another being, which we now know from our discussions in the first two major sections. This ability, in its elementary form, has been found to be present in our closest genetic relatives, the chimpanzees (Mithen, 2008). Brain size is directly linked to this capacity (Dunbar, 2004) in the case of the Early Homo species (see Figure 4). In the *second* step, Mithen talks about how the different stages in the life history of a human contributed to the development of the capacity to imagine, namely – infancy, childhood, adolescence, adulthood and old age. During infancy, childhood and most of adolescence, the subject is dependent on others for many things and brain growth occurs rapidly within a social group, where knowledge and thinking abilities are given shape. Adulthood and old-age are the phases in which the subject gains experience and learning, which he passes on to the subsequent generations. Bogin (1999) suggested that childhood appeared with the earliest Homo and adolescence only with *Homo sapiens*, while others (O'Connell et al., 1999; Hawkes et al., 1997) argue that old-age lifespans evolved with *Homo erectus*. The capacity to imagine has been the result of these extended phases of childhood and adolescence.

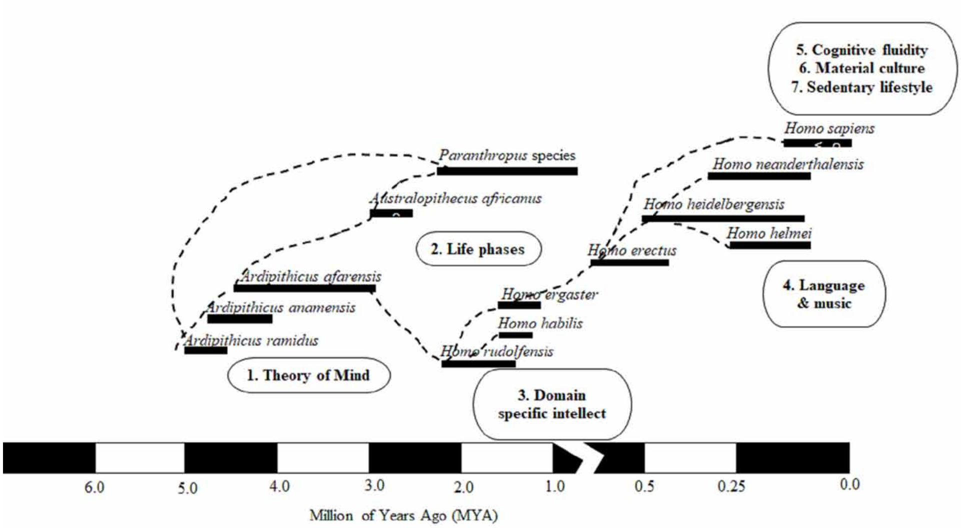
The *third* step discusses the role of evolution of domain-specific intelligence in creative imagination. The most convincing evidence concerns the foresight of tool-use. Boesch and Boesch (1984) described how chimpanzees in the Taï forest of the Ivory Coast carry hammer stones to nut-trees, frequently carrying these over short distances and selecting the most direct route in the process. Thus, they seem to foresee nut-cracking and consciously select stones for that purpose. Similarly, Goodall (1986) observed that chimpanzees at Gombe prepare termite sticks in advance, even in the absence of termite mounds that clearly shows the involvement of planning and imagination. The brain size of *Homo floresiensis* (Brown et al., 2004) was below 400 cc which is less than that of a modern-day chimpanzee, still, this species seems to have made stone objects and took part in big game hunting. With the evolution of dedicated mental elements for interaction with social, natural, and physical worlds, Later Homo (*H. heidelbergensis* and *H. neanderthalensis*) developed a 'domain-specific' mentality (Mithen, 2008), i.e., they possessed complex cognitive processes comparable to modern humans, but these were limited only to specific domains of activity. This ability allowed imaginative thought within these domains, that provided the raw materials for the creative explosion. One of the most characteristic objects of the Later Homo age is the hand axe which is believed to have been an example of the creative imagination. In the *fourth* step, Mithen discusses the evolution of language and music. Fossil evidence indicates that *H. neanderthalensis* and *H. heidelbergensis* had a larynx (voice-box) that was indistinguishable from that of modern man (Arensburg et al., 1989; Clegg 2012) meaning that these species may have had a language of sorts. However, archaeological evidence suggests otherwise. Mithen (2005) postulated that Later Homo had a communication system with five essential characteristics – holistic, manipulative, multimodal, musical and mimetic, that further acted as a precursor to language and music development. Early communication systems lacked words and grammar, and used gestures, a possible proto-language (Bickerton, 2003), facial expressions, variations in pitch, frequency, tempo, rhythm, etc. The *fifth* step, development of cognitive fluidity, was a result of the evolution of language as a medium of exchange of ideas and

Figure 4. Taxonomic classification of Primates (Based on data from Mader & Windelspecht, 2016)



experiences. This led to the generation of new ideas, founding cultures. The first representational images that are the most notable examples of imaginative abilities were found in cave paintings, rock art, religious ceremonies of hunter-gatherers, body ornaments, specialized tools, etc. These artefacts and ideologies were seen in the late *H. neanderthalensis* and *H. sapiens*. The *sixth* step, development of material culture, was made possible by the advent of cognitive fluidity. The most striking evidence of this is the belief in religious supernatural beings, and religious ceremonies performed in their name. Artefacts supporting this hypothesis has been found in the Ice Age carving of the 'lion-man' of the Hohlenstein-Stadel. It is the oldest known example of figurative art and was carved out of mammoth ivory using a flint stone knife. The figurine has the head of a lion and the body of a male human, which suggests that the Palaeolithic humans may have been practicing

Figure 5. Seven-step evolutionary process of the imagination (Based on Mithen, 2008)



shamanism and believed in mythology (Coolidge & Wynn, 2018). In the *seventh* step, sedentary and farming lifestyles emerged that paved the way for the invention of writing as a means of communication and record keeping. The development of such sedentary and farming lifestyles, further, increased the imaginative potential of modern human minds.

Whiten & Suddendorf (2008), stated that the evolutionary roots of human imagination could be found in great apes, our closest relatives. They gave much evidence to support their claims that the great apes – chimpanzees, gorillas and orangutans, exhibited imagination at two levels, namely, inventiveness and pretense. Some of these aspects were also presented by Mithen (2008, 2005). The fact that imagination was not present from the beginning but evolved in humans from the great apes and other animals suggests that it played an essential role in providing those species that possessed it, a better chance for survival. Imagination played a crucial role in many day-to-day activities like foraging for food, protection from hazards of the environment, evading predators, mate selection, etc. Thus, species that were able to utilize this capacity for such purposes were better adapted to survive in changing environments, and this resulted in the evolution of these skills to higher capacities as they were selected for, via natural selection (Darwin, 1859).

The Neurobiology of Imagination

Agnati et al. (2013) defined the imagination in neurological terms as follows: "Imagination is the capability of neural circuits to combine in novel ways, images, with a direct perceptual origin and concepts to produce original images and speculations." Imagination is required to do a lot of things – anticipate the future, construct fantasy, simulation, recall, empathize with others, etc. The complex human brain is the source of our consciousness and all thought, and therefore, the least understood of all human organs. The objective of neurobiology, hence, is to uncover how the brain thinks and acts. The investigation of meaning and imagination requires cognitive science, neuroanatomy, psychology, philosophy, linguistics, etc. According to Boden (2006), the neuroscientific explanation of the imagination should not only focus on which areas of the brain or, which neuronal circuits are active when this psychological phenomenon occurs, but also on what these neurons are doing and how they are doing it. These activities of the neurons are not to be understood only through the chemical changes that occur, but, more importantly, in terms of the computations and information processing that these neurons are performing. In the following subsections, we will throw light on the concepts of mirror neurons, metaphor formation and largescale networks in the brain, especially the default mode network. Let us first take a very brief tour of the human brain and thereafter consider the more important questions of how these brain cells represent and process information to give rise to the phenomenon of the imagination.

Neurons and the Human Brain

The brain is the central organ of the nervous system of an organism. The mammalian forebrain (anterior part) has an additional outermost layer called the *neocortex* that functions in higher mental processes like spatial reasoning, conscious thought and language (Mader & Windelspecht, 2016). Furthermore, the neocortex of primates is different from that of other mammals. The cortical frontal lobes of primates are large, complex, and have several crevices and folds that increases the surface area and number of connections between regions. In humans, other parts of the cortex are also enlarged in addition to the frontal lobes, forming highly intricate connections with different parts of the brain (see Figure 6). This unique brain capacity allowed mammals, and especially humans to better adapt, and become adept at higher metal faculties like manipulation of the environment, complex learning, anticipating the future, etc (Mader & Windelspecht, 2016).

The cerebral cortex of a human brain is the region where consciousness originates. It contains about 25 billion neurons (brain cell or nerve cell) arranged in six layers, with a staggering 10^{14} interconnections or synapses (Vanderah & Gould-Nolte, 2015). Neurons are a functional unit of the nervous system and differ in appearance depending on their function and location. Neurons consist of three major components – a cell body (soma), an axon, and dendrites (see Figure 7). Dendrites (tree-like structures) receive signals from sensory receptors or other neurons and transmit them to the cell body. Axons transmits information to other neurons or cells via electrical conduction at synapses (junctions). Some axons are covered with an insulating layer called the myelin sheath that helps to speed up the transmission of electrical impulses across the axon.

The most abundant type of neurons in the neocortex of the cerebral cortex are pyramidal cells that have a conical shape from which a long apical (topmost) dendrite as well as many basal (lower) dendrites emerge. These cells have a long axon that spreads to other cortical areas of the brain to make synapses. The topmost neocortical layer is known as the *molecular* layer that consists of only a few cells. Layer II is called the *external granular* layer contains small pyramidal neurons and numerous stellate (granule) cells. Layer III is the *external pyramidal* layer, containing small and medium sized pyramidal cells. Layer IV, the *internal granular* layer, contains small, irregular stellate cells. Layer V, the *internal pyramidal* layer, contains large pyramidal cells. Layer VI, the *polymorphic* layer, contains many small, modified, fusiform pyramidal cells, and a few large pyramidal cells.

Metaphor and the Imagination

Lakoff and Johnson (1980, 1999) have shown that metaphor (analogy) is not only a figure of speech, but a form of thinking or cognition, that functions as an interpreter of unconscious memory. Modell (2003) argues that metaphors transfer meaning between dissimilar domains and can further transform meaning and generate novel perceptions, without which, imagination cannot exist. Modell thus supports the views of Gaut

Figure 6. Major lobes of the human brain. a. Lateral view (left hemisphere). b. Parasagittal view (right hemisphere) The corpus callosum is a bunch of nerve fibres bridging the left and right hemispheres.

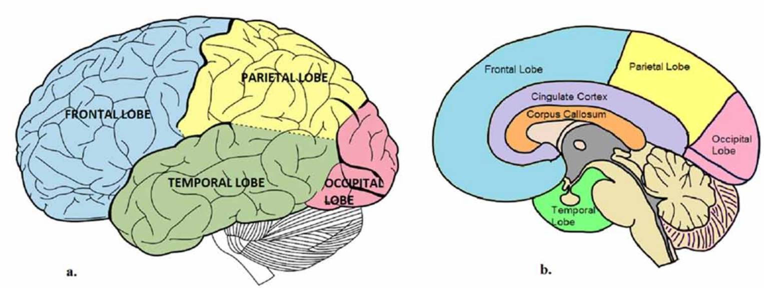
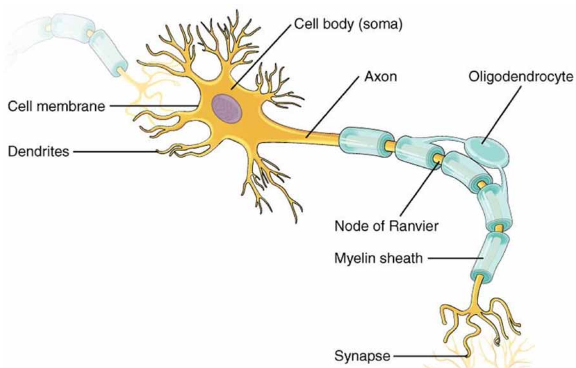
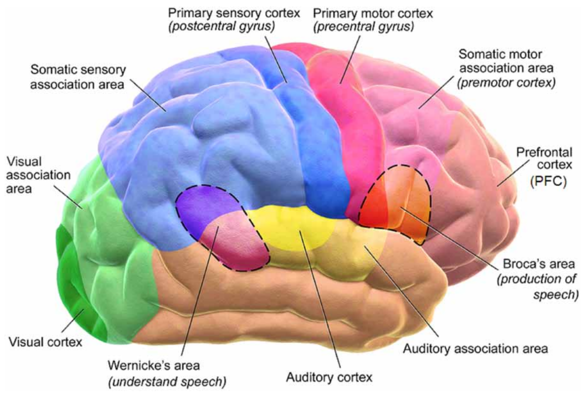


Figure 7. Anatomy of a typical neuron (Source: OpenStax, 2016). Oligodendrocytes are a type of glial cells (support cells) that form the myelin sheath. Gaps between myelin sheath cells are called nodes of Ranvier.



and Kant regarding metaphor formation and its significance in creative imagination. He insists that the unconscious, creative imagination requires long term memory and a related process linked via metaphor. Metaphor construction is essentially multimodal, involving the visual, auditory, and kinaesthetic inputs. Since the faculty of metaphoric thinking is uniquely human, the *prefrontal association cortex (PFC)* (see Figure 8), which is significantly enlarged in humans as compared to primates and has rich connections to the limbic system (that deals with emotions, memories and arousal), is active in unconscious metaphor formation (Deacon, 1997; Changeux & Connes, 1995). Lakoff (2014), proposes a model for complex metaphorical thought as neural binding circuits, wherein the complex metaphors are themselves made up of embodied primary metaphors. Neural binding circuits bind neural schemas (a pattern of thought or behaviour that organizes types of information and their associations) in different brain regions, making the brain both multimodal and cross modal. Primary metaphors are primitive neural circuits that bind primitive neural schemas together, when these are regularly activated simultaneously due to everyday experiences (Hebbian learning). Primary metaphors are moulded beginning from the neuro-embryonic development phase i.e. the development of neural maps composed of neural circuits. Edelman (1987) explains that this process exhibits Darwinian selection, in which, through the process of cell division, growth and selection, local neural sites are established. Thereafter, neurons in the embryo thrive, find nutrition, and undergo developmental selection, then experiential selection. Developmental selection results from growth factor signalling and selective pressures that yield anatomical networks in everyone (Edelman, 1989). Experiential selection is based on Hebbian association of neuronal synapses, wherein, certain neural synapses are either amplified or dampened depending on the environmental conditions and the

Figure 8. Major brain cortices and association areas (Source: Blausen.com staff, 2014)



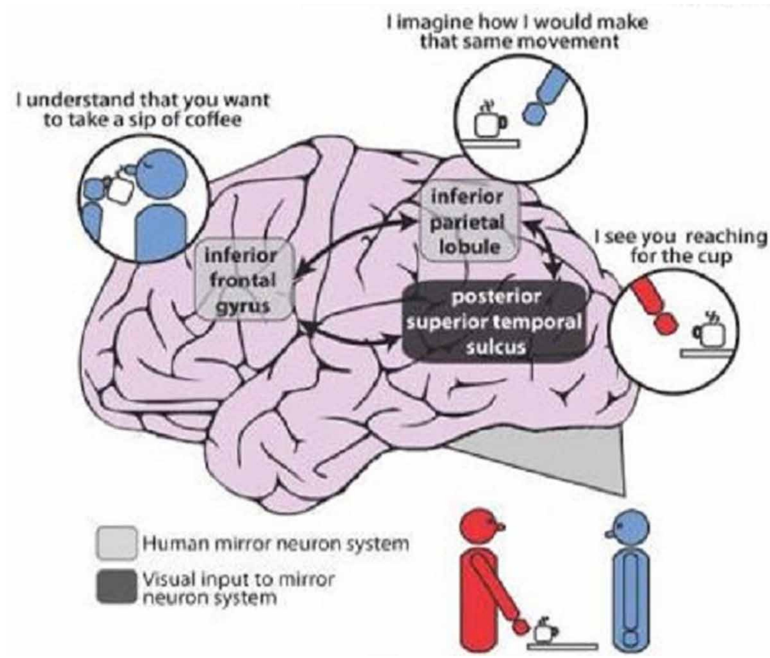
behaviour of the subject. According to Hebb's rule (Hebb, 1949): "When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased."

Therefore, some neural circuits are strengthened, and some are pruned or become extinct, like the natural selection processes of Darwin theory of evolution (Darwin, 1859). Edelman termed this process as Neural Darwinism which is both indeterminate and nonlinear in nature. Neural circuits, in turn, form larger assemblies called neural maps by the grouping of neuronal circuits that fire together. Edelman & Tononi (2000) elicited another process called re-entry where these neural maps are coordinated by the distributed parallel selection and correlation of neuronal groups in different brain regions, creating complex meaning. This type of reorganization, correlation, coevolution and selection cannot be predicted and even described in complete detail. Neural re-entry depends upon the remarkable massively parallel reciprocal connection of the brain areas (Edelman, 1999), exemplified by the *corpus callosum* (see Figure 6), a massive bundle of shared neural fibres that connect the two cortical hemispheres (left and right cerebral hemispheres) that synchronize in an ongoing, recursive interchange. Edelman suggested that these processes display plasticity, a property that has been described as inherently imaginative. People perform new and imaginative functions by, and together with, the new-fangled neuronal organizations that becomes embodied in them.

Mirror Neurons and the Imagination

Rizzolatti and Craighero (2004) described a mirror neuron system as a class of visuomotor neurons, originally discovered in the premotor cortex of the monkey, that fires both when the monkey does an action and when it observes another monkey or human doing a similar action. They further showed that a similar mirror neuron system exists in the human brain's *motor cortex*. However, the mirror neuron system of humans is unique in two ways – first, these mirror neurons are activated in the presence of meaningless intransitive movements (Fadiga et al., 1995; Maeda et al., 2002; Patuzzo et al., 2003) and second, that these systems also code for movements forming an action. Rizzolatti and Craighero (2004) performed brain imaging studies to locate the areas of the brain where mirror neuron activation was discovered. They found that transitive actions activated the *frontal* and *parietal* nodes of the mirror neuron system, whereas, intransitive actions activated only the *frontal* node. Mirror neurons are significant for survival of a species as they help in understanding, imitating and anticipating the actions of others. Brascamp (2014) illustrated the mirror neuron process in humans by giving an example of motor action being observed, understood and imagined. Here, a subject observes another reaching for a coffee mug and mirror neurons in the *parietal* and *frontal* areas aid in imagining the anticipated action and understanding that the doer wishes to drink the coffee from the mug (see Figure 9). Gallese (1996) suggested that similar neurons are activated when we perform an action, when we observe that same action and when we imagine or think about those actions. Mirror neurons also help to explain the representations of one's own as well as others' actions. Filimon et al. (2007) showed that observed action as well as imagined action activates the *superior and inferior parietal lobes*, *intraparietal sulcus*, the *praecuneus*, as well as *premotor cortex*. Similarly, other researchers (Gerardin et al., 2000; Kosslyn et al., 2001) have also shown that similar regions of the brain are activated in motor imagery (dynamic brain state where a subject simulates an action in the mind) and actual motor action of the same kind. Most of these studies point to the same regions, like, the *premotor cortex*, *parietal cortex*, *supplementary motor areas*, *sensory cortex*, *amygdala*, and parts of the *basal ganglia*. Mirror neurons play a role in not only motor actions, but, also in mirroring emotions such as pain, anger, hurt, etc. Rizzolatti et al. (2009), showed that the *cingulate cortex*, *adjacent frontal operculum* and *insula* are activated when someone observes these emotions in others as well as when they experience these emotions themselves.

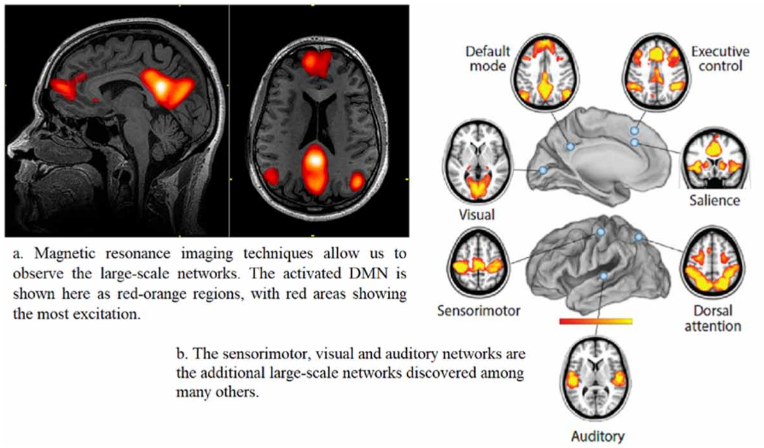
Figure 9. Example of the mirror neuron system (Source: Brascamp, 2014)



Default Mode Network and the Imagination

The default mode network (DMN) is one of the four major large-scale brain networks identified by statistical analysis of functional magnetic resonance imaging (fMRI) blood oxygen level-dependent (BOLD) signals. Other important large-scale networks (Beaty et al., 2018) are the dorsal attention network (DAN, *superior parietal cortex* and *frontal visual fields*), the salience network (SN, *bilateral insula* and *anterior cingulate cortex*) and the executive control network (ECN, *dorsolateral prefrontal cortex* and *anterior inferior parietal lobe*) (see Figure 8 Figure 10). Raichle et al. (2001, 2015) described the default network as consisting of *medial temporal*, *posterior cingulate cortex*, *medial praecuneus*, *inferior parietal* and *prefrontal* regions of the brain. The DMN remains active during the brain's resting state as well as during cognitive tasks such as daydreaming, mind-wandering, anticipation of the future, self-referential judgements, recollection of memories, emotional processing, stimulus independent thoughts and spontaneous cognition (Mason et al., 2007; Andrews-Hanna et al., 2010; Gusnard et al., 2001; Raichle et al., 2015). Thus, the DMN never shuts off and its activity only either reduces or is attenuated (Raichle et al., 2015). fMRI studies have indicated that the DMN plays a role in self-generated mental processes like the imagination, metaphor formation, and creativity (Zabelina & Andrews-Hanna,

Figure 10. The default mode network and other large-scale networks. b. shows the brain activity of all major large-scale networks under fMRI studies (Image source: Raichle et al., 2015).



2016; Beaty et al., 2016, 2017, 2018; Christoff et al., 2016). Beaty et al. (2018) studied the neural basis of imagination in the context of "Openness to Experience" (a Big Five personality trait embodied by the tendency to participate in imaginative, creative and abstract thought). They showed that people having a high degree of Openness had a greater efficiency of information processing with the DMN. Beaty et al. (2015) conducted a study on the other large-scale network interactions and found that divergent thinking (a characteristic of imaginative thought and creativity) activated the ECN and SN. Interactions between the DMN and ECN have also been reported during activities involving imagination and goal directed cognition (Beaty et al., 2018). Visuo-spatial planning is associated with interactions between the ECN and the DAN (Spreng & Schacter, 2012) and intentional mind wandering seems to involve the cooperation of the DMN along with the ECN (Golchert et al., 2016).

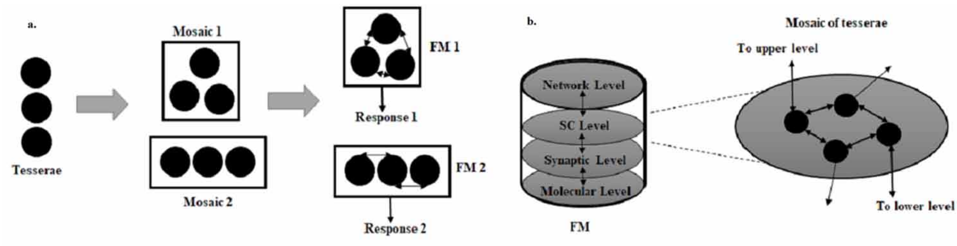
The Von Economo Neurons and the Imagination

Several researchers suggested that imagination is possible only in subjects that are completely self-aware of themselves (Hobson et al., 2006; Jackson et al., 2012). A class of projection neurons called the von Economo neurons (VENs) seem to play a significant role in imagination as they are responsible for the characteristic self-awareness of humans. The VENs are large bipolar neurons that are typically located in the *frontal insula* and *anterior cingulate cortex (limbic areas)* of the human brain (Allman et al., 2011). They have simple dendritic structures that carry basic information from these areas to other regions of the brain quickly (via rapidly conducting large axons) over long distances. The apical and basal dendrites of the VENs are curiously symmetrical suggesting that VENs may be involved in comparing inputs from these dendrites (Agnati et al., 2013). The dendritic architecture of VENs further suggests that they receive integrated inputs from pyramidal neurons. Allman et al. studied the selective destruction of these VENs in the degenerative diseases of the brain, especially frontotemporal dementia (FTD) patients using fMRI, and found that these neurons play a major role in empathy, self-awareness, self-control, abstract thought, etc. All these properties are consistent with our earlier definitions of the imagination.

A Modern View of Imagination in Neuroanatomy

Agnati et al. (2013) stated that the brain is an interaction-dominant dynamics system where it is difficult to assign stringent functionalities to any specific brain region and synchronized processes can transform the inter-relationships and integrative activities of the various neuronal groups. They proposed that exaptation (Gould & Vrba, 1982) and redeployment led to the dynamic organization of neuronal groups. Exaptation is the evolutionary process by which the neuronal groups acquired functionality that they were not originally adapted for. These neuronal groups dynamically organize themselves into what is termed a functional module (FM, Agnati et al., 2012; Agnati & Fuxe, 1984) that can integrate several inputs to give a desired response. These FMs are structured as a partially overlapping, three-dimensional, nested hierarchy of networks from the molecular level to the circuit level without any definite boundaries delineating specific FMs. Therefore, the components of these FMs can be provisionally organized into any number of possible combinatorial assemblies. These FMs and the individual components of these FMs communicate using two modes of transmission (see Agnati et al., 2006; Agnati et al., 2010) – wiring transmission (WT) and volume transmission (VT). Wiring transmission is realized by physical connections called gap junctions and chemical synapses. The channel thus formed between the source and target neurons is a private channel. VT, on the other hand, is characterized by a non-private channel between the source and destination cells using the intricate pathways of electrical and chemical signals through the *extracellular matrix* (ECM) in the *extracellular space* (ECS) of the brain. *Astrocytes* (the most abundant neuroglial cells) also play an important role in formation of synapses and gap junctions, as well as in controlling the chemical environment (ECS and ECM) around neurons. Connected by gap junctions, astrocytes signal each other, creating slow-paced intracellular calcium waves, and by releasing extracellular chemical messengers, also influence neuronal functioning and participate in information processing (Marieb & Hoehn, 2013). This shows that astrocytes play a major role

Figure 11. FM Organization (Based on Agnati et al., 2013) a. Horizontal organization. b. Vertical organization



in organizing FM structures or mosaics by affecting the assembling processes of the synapses that are located nearby, to form a synaptic cluster (SC).

The FM mosaics can be organized either horizontally or vertically (see Figure 11, also see Agnati et al., 2013). In horizontal mosaics, elementary units in a FM are called tesserae (that are in turn made up of VENs, pyramidal neurons, etc.) that can be assembled in different topologies to form different mosaics, thereby reusing the same set of tesserae, exhibiting emergent properties (a characteristic of imagination). The interactions between the tesserae and their order of activation determine the response of the functional mosaic formed. In the vertical alignment, each FM consists of mosaics at various levels of computation, viz. network, SC, synapse, molecular. These mosaics communicate with each other vertically and the individual components of the mosaic further communicate with each other horizontally (at the same or different level). In both, horizontal and vertical alignment, the communication between the various components of the FM occurs through the two modes of transmission described earlier – WT and VT. The communication channels in both the transmission mechanisms contain 'modifiers' (*astroglial* cell arrangements, neurotransmitters, extracellular environment constitution, etc.) that act as learning functions (that respond to changes in the environment) which guide the flow of information through the tesserae and govern the integrative functions of the FMs. Due to all these features, a staggering combination of integrative functions produce the intangible expanse of responses by redeployment and reuse of tesserae as well as the reuse of the plasticity of connection and modifiers. This may result in the fine tuning of responses and may even lead to the emergence of imagery and imagination as well as creativity (Agnati et al., 2013).

Thus, the existence of imagery neuron systems (INS) can be suggested in the context of the exaptation and redeployment hypothesis, and of the interaction-dominant dynamics triggered by VENs to form FM mosaics acting as hubs (Anderson et al., 2012). According to Agnati et al. (2013), then, the INS and VENs, under the control of the DMN may provide the neurobiological substrate for an effective colossal redeployment (Anderson, 2007) of local networks to many different higher-level cognitive tasks such as imagery, prospection, and imagination.

THE NEUROBIOLOGICAL CORRELATES OF CREATIVITY

We have already established the relationship between imagination and creativity in the sense that creativity implies imagination, but, imagination does not imply creativity. This is to say that in any act of creativity, imagination plays a significant role. Creativity is considered the highest level of cognitive thinking that steers artistic, scientific, cultural and technical advances (Kaufman et al., 2010). Therefore, it is also the most difficult to explain in terms of the information processing mechanisms that are involved, from the viewpoint of neuroscience and cognitive neurogenetics. However, since we have established the information processing neural substrates of the imagination, we may conclude that similar processes are involved in creativity.

Evolutionary Perspectives of Creativity

Early humans needed creativity as a means for improving their survival tactics, defeating competition for sexual selection, acquiring food, warding off predators, social bonding, etc. Gabora & Kaufman (2010) suggest that the initial evidence of creativity was found in the earliest human invention – the Oldowan artefacts (simple, non-specialized stone tools pointed at one end, some with sharp edges) attributed to *H. habilis* (Early Homo; Semaw et al., 1997) and possibly, australopithecines (Later humanlike Hominins; de Beaune, 2004) (Figure 4). Specialized tools (e.g. hand axe) for big game hunting and other survival strategies, appeared with *H. erectus*. Donald (1991) proposed that creativity arose due to the transition of episodic cognition to mimetic cognition from *H. habilis* to *H. erectus*. He stated that *H. erectus* acquired a 'self-triggered recall and rehearsal loop' that helped him to anticipate future events based on memorized past experiences. He could trigger such loops in others through gestural communication, develop a train of thought, evaluate and refine responses through repetition and simulation, and adapt to changing situations. This led to the invention of new and improved specialized artefacts. With the advent of the Upper Palaeolithic era, a cultural explosion was seen (Mithen, 1996). Evidence shows that cultural artefacts of this era build upon earlier ones, enhancing their functionality (Gabora & Kaufman, 2010). With the appearance of *H. sapiens*, first-order intentionality transformed to second-order intentionality or theory of mind (Dennet, 1976). These transitions are in accordance with the seven-step evolutionary processes discussed previously that were elicited by Mithen (2008). Creativity is not only known to evolve from a biological perspective, but also from culture. Gabora &

Kaufman (2010) argue that evolution of creative ideas from culture mimicked how life began on our planet. They say that, through self-organization and communal exchange of innovative ideas, and the adaptive and open-ended nature of this self-organization process, creativity was impelled via cultural evolution.

A Genetic Basis for Creativity

Several research studies have been carried out to explore the underlying genetic basis for creativity, but with mixed results. Creativity is multi-faceted rather than a single trait, and these studies have addressed different aspects of creativity (like divergent thinking), thereby giving unsatisfactory results. To truly study the genetics of creativity, one needs not only to explain the genetic basis of intelligence, but also the genetic basis of an individual's personality. Various twin and adoption studies, genome-wide association studies (GWAS) have been done to locate the genes responsible for the heritable characteristics of intelligence (Davies, et al., 2011; Deary, Johnson, & Houlihan, 2009; Deary, Penke, & Johnson, 2010; Butcher et al., 2005; Dick et al., 2006; Luciano et al., 2006). Davies et al. (2011) suggest a polygenic model, where many genes contribute a small percentage to have a cumulative effect on intelligence. As regards personality, genetic studies have targeted such traits as risk-taking, openness to experience, novelty seeking, etc. (Curtis, 2004; Benjamin et al., 1996; Beaty et al., 2018; Roe et al., 2009; Ebstein et al., 1996; Lerman et al., 1999). These studies also point out the polygenic nature of personality traits. It is now common knowledge that a trait that is expressed is governed not only by the genetic makeup of the DNA (Deoxyribonucleic acid), but also by the environmental factors that the subject is exposed to. This is especially important in the context of creativity and the effect of cultural transmission on this multifaceted trait. Talented parents, who are highly creative in their field (say, music, arts, mathematics, etc.) can provide a conducive environment for their children to express this trait more effectively. Such children get additional benefits of training, practice and encouragement starting from a very early age, that helps them to develop their own novel ideas (creativity) based on the what their elder family members pass on to them, both culturally as well as genetically.

The Neurobiology of Creativity

We have already discussed some aspects of the neural correlates of creativity in previous sections when we explored the neural basis of the imagination. We talked about how the DMN in collaboration with other large-scale networks and the INS (including the FM mosaic assemblies) may be responsible for the imagination as well as for creative thought. In this section, therefore, we will investigate two more perspectives of creative cognition and its neural substrates.

The first view posits a hemispherical asymmetry (Bogen & Bogen, 1969) in the emergence of creative thought. According to the notion of hemispherical asymmetry, analytical abilities of the brain (involved in scientific and mathematical thinking) were attributed to the left hemisphere and holistic thinking (freedom of expression, artistic thinking, creativity) was attributed to the right hemisphere. Experimental studies with EEG (Electroencephalography), fMRI, measurement of ERP (event related potential) show that creativity tasks result in higher right hemispherical activity (Razumnikova & Larina, 2005; Aghababyan et al., 2007; Mashal et al., 2007; Howard-Jones et al., 2005). However, Bogen & Bogen (1988) later reinstated their theory on the emergence of creativity after studying the brain activity in patients whose hemispheres were dissociated due to the severance of the bridge (*corpus callosum*) that connects them. They now stated that creativity resulted from the collaborative efforts of both the hemispheres with the help of the *corpus callosum* acting as a bridging coordinator.

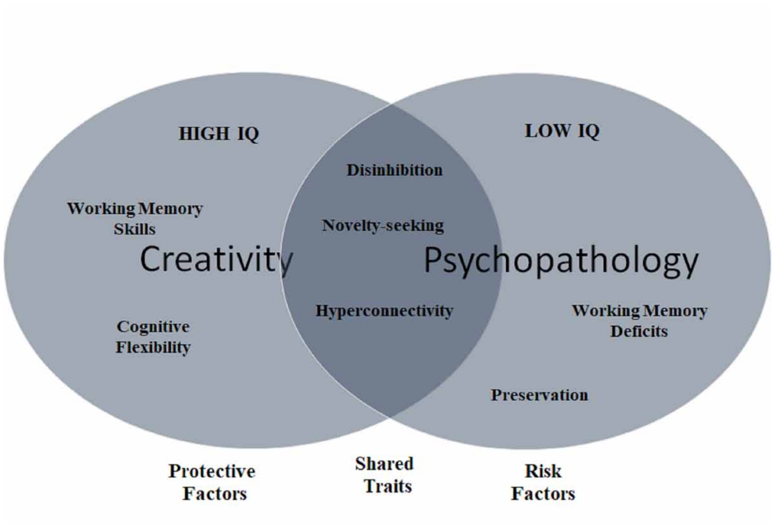
The second view postulates that creativity stems from the disinhibition in the frontal lobes (Martindale, 1999). Martindale argued that creative feats are a result of defocused attention (where many mental representations are simultaneously active) and associative thought. He performed EEG alpha-wave analysis on the cortical activation patterns of the brain and concluded that increased activation in the cortices inhibits other brain processes that are required for novel recombination (Martindale, 1971, 1977, 1989, 1999). Therefore, the reverse, i.e. the lowered activation of these cortical areas induces creative thought.

Creativity and Degenerative Diseases of the Brain

"No great genius has ever existed without a touch of madness." - Aristotle

The stereotype of a 'mad-genius' proposes that creative people often tend to suffer from some sort of mental illness. Not only creative geniuses in the fields of the arts, but also in the fields of science and mathematics have given examples of having creative ideas while suffering from a mental illness. Isaac Newton was known to suffer from bipolar disorder (not called so at the time) and suffered from several nervous breakdowns and frequent fits of rage. Ludwig van Beethoven, the famous music composer, also suffered from bipolar disorder and his greatest compositions have been known to stem from bouts of mania. Vincent van Gogh, the famous painter, suffered from mood disorders and epileptic seizures, possibly due to alcohol and substance abuse. Nikola Tesla, the incredible genius, was rumoured to have shown signs of autistic spectrum disorder as well as hallucinations. Virginia Woolf, the famous British novelist, also experienced the mood swings of bipolar disorder. John Nash, the famous mathematician, was diagnosed with schizophrenia at the peak of his career. Ernest Hemingway, the famous poet and writer, was a known alcoholic. Actors, musicians, writers and artists are generally known to turn to alcoholism and substance abuse to conceive creative feats, which in turn, results in episodes of depression, mood swings, etc. Many researchers studied these mental illnesses in creative professionals and concluded that milder variants of these disorders were likely to enhance creativity, however, acute forms of the disorders interfered with and dampened creative abilities (Richards et al., 1988; Andreasen, 1987, 2008; Jamison, 1989). Studies show that creative people tend to be at a greater risk of developing mental illnesses and this relationship is genetically heritable (Andreasen, 1987; Jamison, 1993). Studies of the relation between creativity and schizophrenia found that creative people suffering from schizophrenia have an overinclusive or loose thinking style (Maher, 1972; Andreasen & Powers, 1975) that fosters creative ideas. However, these studies pointed out that after diagnosis of these psychotic disorders, creativity in the individual was hampered rather than enhanced. Thus, subjects exhibiting subclinical traits of psychosis like positive schizotypal characteristics (magical thinking, distorted perceptual experiences) rather than actual schizophrenia, tend to be more creative (Claridge, 1997; Rawlings and Locarnini, 2008). Similarly, substance abuse and alcoholism are linked to creativity in the same way as are schizophrenia, bipolar and mood disorders. Progressive substance abuse tends to decrease creativity and destroys the life of such individuals. Carson (2013) postulated three models of the relation between creativity and mental illness. In the first model, she discusses the question whether creativity causes or enhances mental illness. Creative lifestyles put people at risk of mental illness. Factors such as loneliness, futility of life, refutation, ridicule, lack of social and economic support, etc. push them towards depression, despair, and onset of various types of mental illness. In the second model, Carson addresses the question whether mental illness enhances creativity, which we have already established. In the third model, she discusses why creative people are at a higher risk of psychopathology than the general public. We already know that creativity is heritable and polygenic in nature. Carson points out that creative individuals share some neurocognitive vulnerability traits that are also found in people with certain forms of psychosis. These shared traits (see Figure 12) may enhance cognitive disinhibition, novelty-seeking, and uncommon associations via uncharacteristic neural connectivity or hyper connectivity of brain areas that normally do not collaborate. Cognitive strengths, like high IQ, good working memory, and cognitive flexibility, may interact with these vulnerabilities to enhance creativity and to act as protective factors against acute forms of psychopathologies (Carson, 2013).

Figure 12. Shared vulnerability model of the inter-relationship between creativity and psychopathology (Based on Carson, 2013). Risk factors are the ones that are characteristics of mental illness. Protective factors are responsible for shielding the creative individuals from developing mental illness.



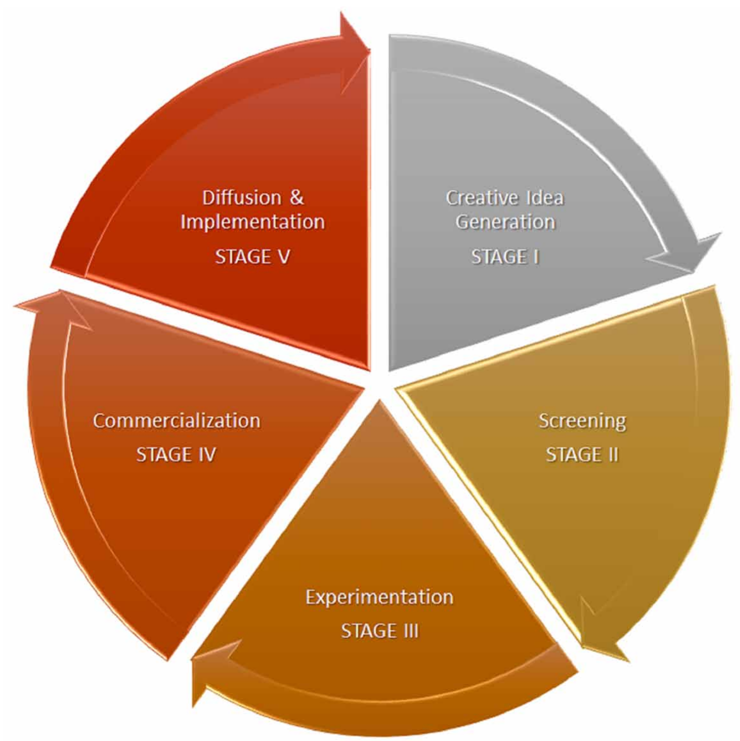
This third model explains the interrelationship between creativity and psychosis very well and may be used in attempting to treat such illnesses with creative tasks, in the future.

CREATIVITY AND INNOVATION

Early human species needed creativity and innovative skills to enhance the chance of their survival and increase the fitness of their species. However, the modern human race needs creativity, not as a means for these primitive goals, but to solve the problems man has created for himself with the ever-growing population and a technologically centric life. Moreover, we wish to create innovative feats in various fields to make a mark in this world, to leave our footprints in historical chronicles, for fame, recognition, appreciation, etc. Then again, there is a subtle difference between creativity and innovation even though these terms are often used interchangeably. Creativity is the cognitive ability of generating new ideas that have some value for humanity.

Innovation is the process of executing these novel ideas to create a new product or implementing that idea in some way. The five stages of the never-ending cyclical innovative process (Desouza et al., 2009) begin with *creative idea generation* or creativity (see Figure 13). Next, these ideas are *screened* to measure the risks and benefits of implementing them and to assess their feasibility. The third stage involves *experimentation* on the ideas that pass the screening stage. If the result is an innovative product, it is tested in a small target market. If it is a process or service, the pilot test may consist of a small control group on which the sustainability of that process or service can be analysed. The successful completion of the experimentation stage determines whether the idea can be commercialized. *Commercialization* is a very important stage, that is often undermined by the creative research individuals as they do not gauge the vitality of this phase. An invention does not become an innovation till it is commercialized. Commercialization helps to analyse the impact, market value and the benefits of rolling out the innovative product or service. The final step is the *diffusion and implementation* phase, where the innovative product or service gains acceptance and resources are then mobilised to mass produce it.

Figure 13. Stages of Innovative Process (Based on Desouza et al., 2009)



Does Creativity Always Lead to Innovation?

Without creativity, there can be no innovation. However, it is also indicated that, not all creative processes result in innovative products. Therefore, it can be concluded that innovation is implied by creativity, but, creativity does not imply innovation. Everyone is creative (Runco, 2004), but not everyone is innovative. There are several barriers to creativity and innovation. Some of these barriers prevent creative ideas form manifesting into innovative products and services. Fear of failure and negative thinking are among the major barriers that inhibit creative ideas from developing into innovative feats. Creativity and innovation depend upon trial and error, knowledge and skills, imaginative abilities, diligence and hard work, thinking out of the box, tenacity, etc. Fear of failing, of ridicule, hampers the creative individual from trying out new associations of ideas and breaks his resolve. He/she may give up too early thinking that risk-taking is not going to achieve anything worth recognition. Stress, lack of resources, lack of time, lack of financial support or motivation are also some of the leading causes that break the chain from creativity to innovation.

Creativity and Innovation in the Fourth Industrial Revolution

Since we have established the inter-relationships between the concepts of imagery, imagination, creativity, and innovation, it can be suggested that innovative feats are a result of the creative imagination of an individual, which in turn, stems from various kinds of mental imagery. Let us now turn our attention to how these cognitive faculties contribute to developments in technological advancements. The fourth industrial revolution (4IR) is defined as (Chaurasia, 2018) “the ensuing era of computing, with the amalgamation of emergent technologies like cognitive & machine learning, artificial intelligence, Internet of Things, wearable technology, biotechnology, 3D printing, smart cities, etc., to create a smart world where everything communicates with everything else intelligently, with the purpose of achieving the unthinkable”. Chaurasia states that we are yet to enter true 4IR and that we are midway between the current Digital Revolution and 4IR. In the following subsections, we will first examine how creative imagination leads to acquisition of knowledge and then look at innovation and creativity in 4IR.

How Creative Imagination Leads to Knowledge Building

Several scientists, artists, musicians and writers have reported experiencing imagery and imagination in association with their most significant discoveries and inventions (see Polland, 1996). Polland studied the personal accounts described, as well as, autobiographies and biographies of famed creative geniuses. Albert Einstein stated that his Theory of Relativity was first conceived as a mental image. In his doctoral thesis, Polland detailed that engineers mostly reported visual imagination as the mode of discovery, whereas, musicians reported auditory imagery as the mode for their famous compositions. Many geniuses also advocated that they achieved their eureka moment when in the incubation phase of creative thinking. James Watt stated that he arrived at the design for improving his steam engine efficiency as a mental imagery episode while taking a walk. Nikola Tesla also reported that he arrived at the diagrams for his alternating current generator while taking a walk with a friend, owing to imagery. Stephen Hawking attributed his research to mental pictures as he could not communicate or write. Euclidean geometry gives a stark example of creative problem-solving using imagination (Beaney, 2010). Descartes too utilized his creative imagination for projecting and synthesizing the mathematical proportional relations. From all these accounts, we may conclude that creative imagination plays a very important role in the acquisition of new knowledge and innovative discoveries. Kind (2018) argued that creative imagination is not exclusive only to extraordinary imagers like Nikola Tesla but is also inherent in ordinary imagers. However, these geniuses are different from ordinary creative imagers in the sense that they can control their imaginings, setting the right constraints and strictly adhering to those constraints. Kind states that one's beliefs about the world act as constraints on the creative imagination and fuel them. Just as computer simulations are governed by the constraint variables that we set, imaginative simulations are also governed by worldly constraints that we set on them. Fabian Dorsch (2016) similarly advocates that a veritable belief meets the externalist conditions of reliability and safety as well as the internalist condition of access to reliability and safety, which is enough for acquiring knowledge. Famed philosophers of previous centuries (section 'Historical Perspectives of Imagination') also stressed the role of creative imagination in knowledge acquisition. Wittgenstein's account of 'seeing-as' talks about viewing problems from different and new angles, so that novel solutions arise. From Aristotle, Kant and Leslie's theories, the importance of sense experiences and rational thought (meta-representation of imagination) in contributing to knowledge, is highlighted.

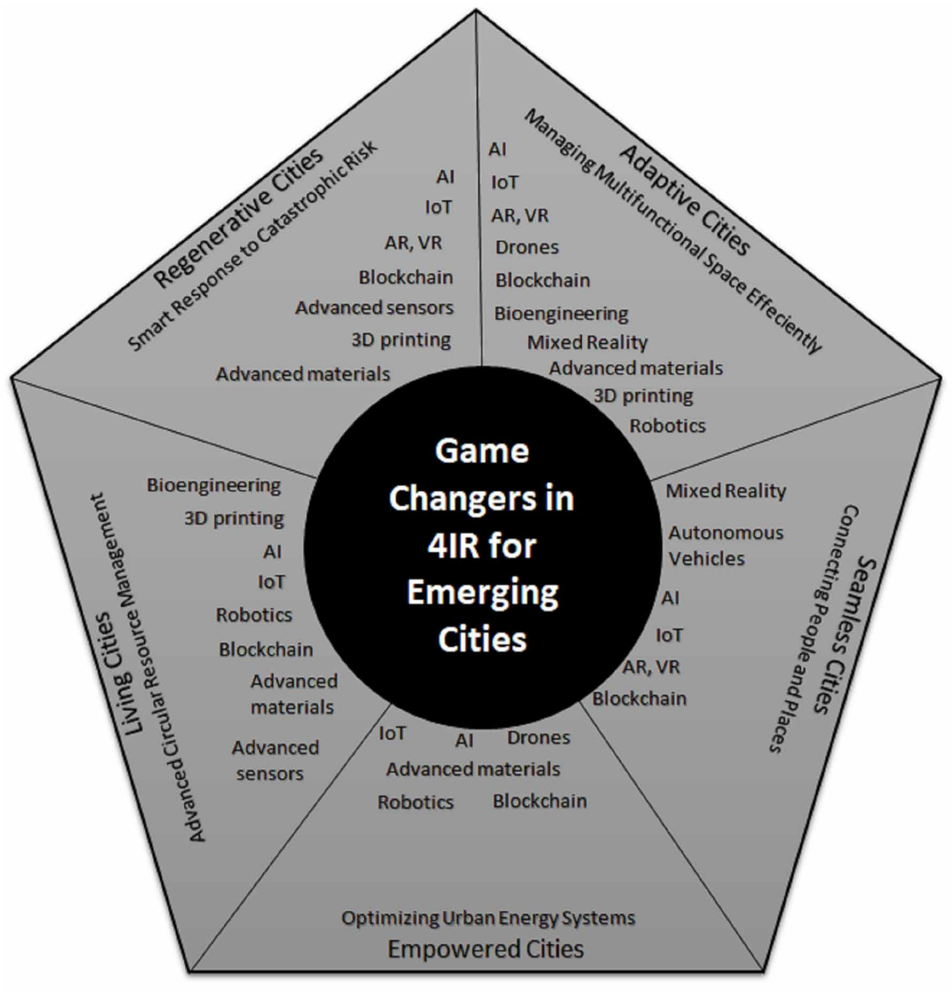
Innovation & 4IR

The Digital Revolution was triggered by the advent of computer systems, automation, information and communications technology (ICT) and the like. However, the 4IR is known as a cyber bio-physical system, where creativity is the main driving force fuelling the fusion of technologies. In November 2018, A.H. Mahmood Ali (Foreign Minister – Bangladesh), said in a workshop on 4IR (Bdnews24, 2018) that we need to employ our imagination, creativity and innovation without hindrance for our schools, factories, companies and government. He also stated that 4IR is a silent revolution that is introducing profound and transformative changes in the thinking, values, life and work of every person, industry and country.

4IR technologies will create novel ways for peoples to connect to each other, to trade with each other, and to access services that are currently unavailable. People gain access to new sources of information (YouTube, e-news, Google, apps), new forms of education such as online courses and virtual classrooms, new healthcare (telemedicine powered by smartphones linked to diagnostic pills, virtual clinics, robotic surgeons) and new financial services (mobile banking, net banking). Advancements in robotics, computing and automation may replace the human workforce, but strategic decision making, creative tasks, innovation, discoveries, etc. cannot be replaced by such technology yet. According to a report by the World Economic Forum (2016), many purely technical jobs are expected to demand creativity and interpersonal skills. The report also shows that creativity is a key skill that will be required for jobs in varied fields such as architecture and engineering, computers and mathematics by 2020. Klaus Schwab (WEF founder and chairman) stated that "Business leaders and senior executives need to understand their changing environment, challenge the assumptions of their operating teams, and relentlessly and continuously innovate." For example, Association of Southeast Asian Nations (ASEAN), in their 49th Economic Ministers Meeting in 2017, noted that the theme of the summit would be innovation-led growth. Their strategic measures for achieving such an innovation driven economy were increasing trade and investments, cross-border investments in MSMEs (micro, small and medium-sized enterprises) and integration of these MSMEs into global supply chains. They discussed that (World Economic Forum & Asian Development Bank, 2017) with the advent of new industries in 4IR, the major challenge would be to curb unemployment and create workers with new skills like creativity and innovative problem-solving abilities. Singapore's Smart Nation and 'Smart Mobility 2030' plan focusses on implementing innovative and sustainable smart mobility solutions, such as, on-demand autonomous vehicles, electric vehicle-sharing programme, autonomous buses and numerous other self-driving vehicles. Other innovative strategies to combat further challenges of environmental degradation, food scarcity, traffic management, healthcare services, etc., have also been suggested in their report. Some of the solutions offered are (World Economic Forum & Asian Development Bank, 2017):

- Reducing the requirement for extensive power distribution networks by localizing renewable energy production,
- Delivery of certain goods through drones,
- Small scale manufacturing using 3D printing technology for remote locations,
- Use of artificial intelligence (AI), remote sensing and drone technology to supervise fisheries and forest activities,

Figure 14. The 4IR innovation 'game-changers' for emerging cities (Based on PricewaterhouseCoopers & World Economic Forum, 2017)



- Automation of irrigation systems and use of blockchain to manage water distribution,
- Smartphones for information in agriculture and renting of farming equipment,
- Use of blockchain technologies for tracking carbon footprint,
- Internet access to remote areas using solar power and other renewable sources.

Different nations have different challenges to meet and the pace of incorporating 4IR technologies may not be the same. Japan is a developed nation facing issues of declining population and workforce (Takenaka, 2018). In this scenario, there is a need for rapid absorption of 4IR services as they already have technological prowess over developing nations. However, for developing nations like Africa and India, the immediate challenges are poverty, inequality and unemployment that must be addressed while slowly imbibing 4IR. These nations have a huge population of unskilled or less-skilled workers which will suffer with automation stealing away their jobs. Robotics will eventually phase out even trades requiring highly skilled personnel. Therefore, there is a need to focus on a holistic approach by applying 4IR technologies to alleviate these challenges (SAKAN, n.d.). This includes sensitizing the people about the aspects of 4IR, introducing STEM based education system, Universal Basic Income (UBI), upskilling existing skilled workforce to inculcate creative intelligence, etc.

Not only this, but governance also needs to be restructured into developing a platform organization, just like Apple's iOS or the Android on smartphones. Google creates an ecosystem for third-party companies to develop and host apps through the Google Play platform. Google is involved in only managing the platform to make sure that the third-party developers strictly follow their policies and guidelines. Similarly, governance can be built on this principle, where third-party stakeholders design and formulate new standards, policies and frameworks, for integrating projects. Therefore, in this model, the governing party will coordinate among these stakeholders to see to it that all runs smoothly, and no rules and regulations are violated while designing and implementing these standards, policies and frameworks of integration.

On similar lines, PricewaterhouseCoopers in collaboration with the WEF, wrote a report on innovative solutions in the 4IR for emerging cities of the world. According to their report (PricewaterhouseCoopers & World Economic Forum, 2017), "the potential of 4IR innovations and their applications to the worlds' most pressing environmental challenges offers insights into the emerging opportunities and risks, and highlights the roles various actors could play to ensure these technologies are harnessed and scaled effectively". Some of their innovative solutions are given below:

- Use of IoT (internet of things), AI, sensors for predictive and real time traffic and pollution management,
- Advancements in low carbon and cleaner fuel production,
- Decentralized renewable energy production and distribution,
- Temperature sensors, smart meters and occupant control systems to effectively and efficiently manage energy and water usage,
- Urban rooftop farming and vertical farms,
- Use of AI and IoT for prediction and communication of disasters in real time,
- Transit-oriented urban mixed-use communities, multifunctional building design, building codes and standards, etc.

The report also discusses five 4IR innovations that are ‘game-changers’ (PricewaterhouseCoopers & World Economic Forum, 2017) that provide opportunities for emerging cities to tackle current and future environmental challenges (see Figure 14). Various 4IR technologies like IoT, AI, AR (Augmented Reality), VR (Virtual Reality), Blockchain, etc. can be used to challenge these issues. For instance, advanced materials like self-healing concrete can help withstand earthquakes, bioengineering can be used to develop living building facades and vertical farms, through the use of drone and robotic technology as well as 3D printers, multifunctional buildings can be constructed easily and efficiently.

All these advancements are centred on the creative and innovative skills of an urban workforce, and world economies need to invest in the creation of such personnel in the future rather than a purely technical workforce. There is a need to retrain existing staff as well as to reshape the education system so as to incorporate such capabilities in early learning. Introduction of STEM (science, technology, engineering, mathematics) curriculum is one solution to this problem. STEM program involves multidisciplinary learning, where teachers may impart knowledge on how to creatively solve real-world problems through innovative projects. Other possible solutions are using information resources from the web like YouTube videos, online learning course materials, interactive learning, project-based learning, learning through storytelling, etc. to bridge the gap between factual knowledge and implementing that knowledge to overcome real-life challenges.

Hence, there is a growing need for human resources with skills that are irreplaceable by automated technologies, such as creativity, cognitive flexibility, innovation, sensitivity, and social skills, as well as the competence to flexibly manage rapid changes. This skill set will aid organisations in finding better solutions to problems and will result in an increase in workforce engagement level, greater flexibility to change, and retention of existing workforce through upskill programmes without the need to hire new experts (Hoen, 2017a). Hoen clearly differentiates the previous paradigm of thinking to a new creative intelligence paradigm. According to Hoen (2017a), creative intelligence is all about applying universal principles of continuous learning and adapting as opposed to learning a skillset once and basing a career over that skillset with occasional upgrades. Instead of rules, guiding principles enable growth, interdisciplinary learning based on practical applications rather than rote learning is encouraged, challenging the workforce to motivate and engage them increases their confidence and helps them rediscover their potential. In order to do all this and more, a heuristic approach has been suggested by Hoen (2017b). It is an infinite three-step process, the first being, *gaining access* to creative intelligence through reflection, dialogue, associative thinking, thinking through play, writing, role playing, contemplation, allocation of space and more time for these activities, etc. Second step is *amplification* of ideas through laboratory building, experimenting, game design, war room activities, ritual design, teaching, presenting ideas, brainstorming, etc. After gaining new knowledge and ideas, the third step is to *cultivate* them to integrate these into the organization, which can be done via practice, creating a ‘garden’ of methods and tools and maintain this garden, eliminating hostile forces that inhibit creative intelligence, sharing insights, reiterating to the first step and doing it all again. Thus, to indoctrinate creative intelligence, we may focus on the disinhibition of the cortices (Martindale, 1971, 1977, 1989, 1999) as discussed in the section on neurobiological substrates of creative imagination as well as the models of creative processes discussed in previous sections.

FUTURE DIRECTIONS: FROM INFORMATION AGE TO IMAGINATION AGE

Currently, in the information age, our economies are governed by a workforce that is technically oriented, where knowledge is the main driving force. However, with increasing automation and the shift to 4IR technologies, this aspect is beginning to transition as well. We are moving forward to a new era beyond the information age, where creativity and imagination are gaining momentum as the major originators of economic value. This new era has been termed the Imagination Age, that, driven by such technologies as virtual reality, augmented reality, mixed reality, IoT, AI, very high-speed internet connectivity, etc., will augment how people and machines can communicate with and between themselves, to create a novel global culture and economy. Nikola Tesla predicted that one day it will be possible for mankind to display on a screen the image that we conjure up in our minds when we imagine something (Tesla, 1919). He also suggested that we will be able to display in images how people think about something.

Already we are making headway in robotics, AI and machine learning. Sophia is the first humanoid robot to be granted citizenship in a country. Sophia is able to use AI, visual data processing, facial recognition, voice recognition, etc. to imitate humans and make simple conversations. Her responses are shared over a cloud network and using blockchain technology, she can refine her responses and may even gain social skills by learning. AI and deep learning programs are also making breakthroughs in acquiring rudimentary imaginative and creative capabilities. For example, Google DeepMind’s AlphaGo program stunned experts when it found a highly imaginative solution move while playing with Go’s world champion Lee Sedol (Rodriguez, 2016). Google’s Brain AI, Simon Colton’s ‘The Painting Fool’ program, Harold Cohen’s AARON, Benjamin Grossers’s Interactive Robotic Painting Machine, make pieces of art autonomously (Moss, 2015). Google’s Brain AI is a more advanced program that has shown signs of ‘seeing-as’ as it has displayed the ability to imagine objects not in the picture during training. The art created by this program has been called 'Inceptionism' by Google. IBM's Watson cognitive platform was used to create a trailer for the movie – Morgan (IBM, n.d.). However, these programmed imaginative and creative feats are nowhere near the high-level cognitive capacities of human brains after which these programs are modelled. We cannot algorithmically represent creativity and imagination as we do not yet understand fully how they really work and what their aspects are. The aesthetic value of creative art is different for everyone. Likewise, the value or impact of an innovative product may be different for different culture groups. These characteristics cannot be programmed into AI, yet, due to our own lack of understanding of them. Therefore, we need to build a deeper understanding of these concepts in terms of neuroscience and neurogenetics to truly create artificial intelligence that is both creative and imaginative. Right now, AI can only augment human creativity and inspire and motivate us to be more innovative. Advances in brain imaging technology like the use of nanobots, and brain reverse engineering to understand and emulate the brain artificially, may steer the collaboration of AI, deep learning and neuroscience to not only create robots that can think like humans, but also in curing degenerative diseases of the nervous system.

Advances in terms of human communication may also result in holographic projection of the self across borders using augmented, mixed and virtual reality. Communication of humans with devices and machines will also be enhanced with innovations in gestural control, voice commands in natural languages, mind control, etc. Numerous other examples of such innovations can be quoted which are beyond the scope of this chapter.

Kurzweil (2005) states that future combination of AI, nanotechnology, and biotechnology will create a world where anything that can be imagined will be possible, raising the importance of imagination as the key mode of human thinking. In a nutshell, it will suffice to say that everything that we can imagine, have imagined and portrayed through fantasy writings, movies, etc. can be constructed into a reality. The age of imagination will thus usher humanity into a new evolutionary paradigm where the human consciousness may become limitless and change the definition of what means to be human.

CONCLUSION

This chapter began with a discussion on the meaning of the concepts of imagery, imagination and creativity as well as their inter-relationships. The processes of imagination and creativity were also elucidated in detail. Next, we examined the philosophical viewpoints of famous philosophers like Aristotle, Descartes, Kant and

Wittgenstein. After considering the historical perspectives of imagination, imagery and creativity along with the modern views of these concepts, we can conclude that various forms of imagery may give rise to imagination. However, not all episodes of imagery are instances of imagination, whereas, episodes of imagination involve for the most part, some form of mental imagery. Creativity and imagination are also correspondingly inter-related. Not all instances of imagination lead to creative feats, whereas, most instances of creative effort involve some form of imagination. Further, we discussed the neuroscientific explanations of imagination and creativity. This section talked about how the development of imagination and creativity contributed to evolutionary advantages, fostering the expansion of *Homo* species throughout the world and the coevolution of culture. Neurobiological substrates of imagination and creativity are similar in many respects as the latter stems from the former. Mirror neurons, VENs, INS, DMN, other large-scale networks and *corpus callosum* coordinate to produce episodes of imagination and creative thought. Degenerative brain diseases and high-level creativity have also been found to be interlinked at some level. In numerous brain imaging studies, it has been shown that individuals who suffer from low levels of degenerative disorders express increased levels of creativity, some of them exhibiting the compulsive need to perform creative tasks. Also discussed at length in this chapter are the inter-relationships of creativity and innovation and how they will steer a new economy in the 4IR and the Imagination Age. All innovative products, services and processes employ cognitive flexibility and creativity in their conception and development. The five-stage innovation process beings with creative idea generation. However, not all creative ideas lead to innovative outcomes. The many barriers to creativity prevent certain ideas from manifesting into innovative creations. In the age of imagination and 4IR, creativity and innovation are the two most important forces driving a paradigm shift. We must therefore strive to train our existing and forthcoming workforce to enhance and build upon these higher mental faculties in order to create a new global economy and culture, where the limits of the human body are pushed forth, blurring the boundaries between what is considered human and what is regarded as non-human.

REFERENCES

Aghababyan, A. R., Grigoryan, V. G., Stepanyan, A. Y., Arutyunyan, N. D., & Stepanyan, L. S. (2007). EEG reactions during creative activity. *Human Physiology*, *33*(2), 252–253. doi:10.1134/S0362119707020193

Agnati, L. F., & Fuxe, K. (1984). New concepts on the structure of the neuronal networks: The miniaturization and hierarchical organization of the central nervous system. *Bioscience Reports*, *4*(2), 93–98. doi:10.1007/BF01120304 PMID:6713088

Agnati, L. F., Guidolin, D., Battistin, L., Pagnoni, G., & Fuxe, K. (2013). The Neurobiology of Imagination: Possible Role of Interaction-Dominant Dynamics and Default Mode Network. *Frontiers in Psychology*, *4*. doi:10.3389/fpsyg.2013.00296 PMID:23745117

Agnati, L. F., Guidolin, D., Cortelli, P., Genedani, S., Cela-Conde, C., & Fuxe, K. (2012). Neural correlates to consciousness. The "Hall of mirrors" metaphor describing consciousness as an epiphenomenon of multiple dynamic mosaics of cortical functional modules. *Brain Research*, *1476*, 3–21. doi:10.1016/j.brainres.2012.01.003 PMID:22322150

Agnati, L. F., Guidolin, D., Guescini, M., Genedani, S., & Fuxe, K. (2010). Understanding wiring and volume transmission. *Brain Research. Brain Research Reviews*, *64*(1), 137–159. doi:10.1016/j.brainresrev.2010.03.003 PMID:20347870

Agnati, L. F., Zunarelli, E., Genedani, S., & Fuxe, K. (2006). On the existence of a global molecular network enmeshing the whole central nervous system: Physiological and pathological implications. *Current Protein & Peptide Science*, *7*(1), 3–15. doi:10.2174/138920306775474086 PMID:16472166

Allman, J. M., Tetreault, M. A., Hakeem, A. Y., Manaye, K. F., Semendeferi, K., Erwin, J. M., ... Hof, P. R. (2011). The Von Economo neurons in the frontoinsular and anterior cingulate cortex. *Annals of the New York Academy of Sciences*, *1225*(1), 59–71. doi:10.1111/j.1749-6632.2011.06011.x PMID:21534993

Amabile, T. M. (1996). *Creativity in context*. Boulder, CO: Westview.

Anderson, M. L. (2007). Massive redeployment, exaptation, and the functional integration of cognitive operations. *Synthese*, *159*(3), 329–345. doi:10.100711229-007-9233-2

Anderson, M. L., Richardson, M. J., & Chemero, A. (2012). Eroding the boundary of cognition: Implications of embodiment (1). *Topics in Cognitive Science*, *4*(4), 717–730. doi:10.1111/j.1756-8765.2012.01211.x PMID:22777798

Andreasen, N. (1987). Creativity and mental illness: Prevalence rates in writers and their first-degree relatives. *The American Journal of Psychiatry*, *144*(10), 1288–1292. doi:10.1176/ajp.144.10.1288 PMID:3499088

Andreasen, N. (2008). Creativity and mood disorders. *Dialogues in Clinical Neuroscience*, *10*, 252–255. PMID:18689294

Andreasen, N. J., & Powers, P. S. (1975). Creativity and psychosis. *Archives of General Psychiatry*, *32*(1), 70–73. doi:10.1001/archpsyc.1975.01760190072008 PMID:1111477

Andrews-Hanna, J. R., Reidler, J. S., Huang, C., & Buckner, R. L. (2010). Evidence for the default network's role in spontaneous cognition. *Journal of Neurophysiology*, *104*(1), 322–335. doi:10.1152/jn.00830.2009 PMID:20463201

Arensburg, B., Schepartz, L. A., Tillier, A. M., Vandermeersch, B., & Rak, Y. (1989). A reappraisal of the anatomical basis for speech in Middle Palaeolithic hominids. *American Journal of Physical Anthropology*, *83*(2), 137–156. doi:10.1002/ajpa.1330830202 PMID:2248373

Bailin, S. (1988). *Achieving extraordinary ends: An essay on creativity*. Boston: Kluwer Academic. doi:10.1007/978-94-009-2780-3

Barbot, B., Tan, M., & Grigorenko, E. L. (2013). The Genetics of Creativity: The Generative and Receptive Sides of the Creativity Equation. In O. Vartanian, A. S. Bristol, & J. C. Kaufman (Eds.), *Neuroscience of Creativity*. Cambridge, MA: MIT Press. doi:10.7551/mitpress/9780262019583.003.0004

Barnes, J. (Ed.). (1984). *The Complete Works of Aristotle* (Vols. 1-2). Princeton, NJ: Princeton University Press.

Baron-Cohen, S. (2006). The biology of the imagination: how the brain can both play with truth and survive a predator. In R. H. Wells & J. McFadden (Eds.), *Human Nature: Fact and Fiction*. London: Continuum International Publishing Group.

Bdnews24. (2018). *Fourth industrial revolution is real, present in Bangladesh: Foreign minister*. Retrieved from: https://bdnews24.com/economy/2018/11/13/fourth-industrial-revolution-is-real-present-in-bangladesh-foreign-minister

Beaney, M. (2010). *Imagination and Creativity* (2nd ed.). Open University.

Beaty, R. E., Benedek, M., Kaufman, S. B., & Silvia, P. J. (2015). Default and executive network coupling supports creative idea production. *Scientific Reports*, *5*(1), 109–164. doi:10.1038rep10964 PMID:26084037

Beaty, R. E., Benedek, M., Silvia, P. J., & Schacter, D. L. (2016). Creative cognition and brain network dynamics. *Trends in Cognitive Sciences*, *20*(2), 87–95. doi:10.1016/j.tics.2015.10.004 PMID:26553223

Beaty, R. E., Chen, Q., Christensen, A. P., Qui, J., Silvia, P. J., & Schacter, D. L. (2018). Brain networks of the imaginative mind: Dynamic functional connectivity of default and cognitive control networks relates to openness to experience. *Human Brain Mapping*, *39*(2), 811–821. doi:10.1002/hbm.23884 PMID:29136310

Beaty, R. E., Silvia, P. J., & Benedek, M. (2017). Brain networks underlying novel metaphor production. *Brain and Cognition*, *111*, 163–170. doi:10.1016/j.bandc.2016.12.004 PMID:28038366

Beghetto, R. A., & Kaufman, J. C. (2007). Toward a broader conception of creativity: A case for mini-c creativity. *Psychology of Aesthetics, Creativity, and the Arts*, *1*(2), 73–79. doi:10.1037/1931-3896.1.2.73

Benjamin, J., Li, L., Patterson, C., Greenburg, B. D., Murphy, D. L., & Hamer, D. H. (1996). Population and familial association between the D4 dopamine receptor gene and measures of novelty seeking. *Nature Genetics*, *12*(1), 81–84. doi:10.1038/ng0196-81 PMID:8528258

Bickerton, D. (2003). Symbol and structure: A comprehensive framework for language evolution. In M. H. Christiansen & S. Kirby (Eds.), *Language Evolution*. Oxford, UK: Oxford University Press. doi:10.1093/acprof:oso/9780199244843.003.0005

Blausen.com staff. (2014). Medical gallery of Blausen Medical 2014. *WikiJournal of Medicine*, *1*(2). doi:10.15347/wjm/2014.010

Boden, M. A. (2004). *The creative mind: Myths and mechanisms* (2nd ed.). London: Routledge. doi:10.4324/9780203508527

Boden, M. A. (2006). *Mind as machine: A history of cognitive science*. Oxford, UK: Clarendon Press.

Boesch, C., & Boesch, H. (1984). Mental maps in chimpanzees: An analysis of hammer transport for nut cracking. *Primates*, *25*(2), 160–170. doi:10.1007/BF02382388

Bogen, J. E., & Bogen, G. M. (1969). The other side of the brain III: The corpus callosum and creativity. *Bulletin of the Los Angeles Neurological Society*, *34*, 191–220. PMID:4902873

Bogen, J. E., & Bogen, G. M. (1988). Creativity and the corpus callosum. *The Psychiatric Clinics of North America*, *11*(3), 293–301. doi:10.1016/S0193-953X(18)30481-7 PMID:3067226

Bogin, B. (1999). *Patterns of Human Growth* (2nd ed.). Cambridge, UK: Cambridge University Press.

Brascamp, J. (2014). *Illustration of the mirror neuron system* Retrieved from Wikipedia wiki: https://commons.wikimedia.org/wiki/File:Illustration-of-the-mirror-neuron-system-by-Jan-Brascamp.jpg

Bricusse, L., & Newley, A. (1971). *Pure Imagination. On Willy Wonka & the Chocolate Factory* [LP]. USA: Paramount Records.

Brown, P., Sutikna, T., Morwood, M. J., Soejono, R. P., Jatmiko, Wayhu Saptomo, E., & Awe Due, R. (2004). A new small-bodied hominin from the Late Pleistocene of Flores, Indonesia. *Nature*, *431*(7012), 1055–1061. doi:10.1038/nature02999 PMID:15514638

Busse, T. V., & Mansfield, R. S. (1980). Theories of the creative process: A review and a perspective. *The Journal of Creative Behavior*, *14*(2), 91–103, 132. doi:10.1002/j.2162-6057.1980.tb00232.x

Butcher, L. M., Meaburn, E., Knight, J., Sham, P. C., Schalkwyk, L. C., Craig, I. W., & Plomin, R. (2005). SNPs, microarrays, and pooled DNA: Identification of four loci associated with mild mental impairment in a sample of 6,000 children. *Human Molecular Genetics*, *14*(10), 1315–1325. doi:10.1093/hmg/ddi142 PMID:15800012

Byrne, R. (2006). *The Secret*. New York: Atria Books.

Cagle, M. (1985). A general abstract–concrete model of creative thinking. *The Journal of Creative Behavior*, *19*(2), 104–109. doi:10.1002/j.2162-6057.1985.tb00643.x

Carson, S. (2013). Creativity and Psychopathology: Shared Neurocognitive Vulnerabilities. In O. Vartanian, A. S. Bristol, & J. C. Kaufman (Eds.), *Neuroscience of Creativity*. Cambridge, MA: MIT Press. doi:10.7551/mitpress/9780262019583.003.0009

Changeux, J.-P., & Connes, A. (1995). *Conversations on Mind, Matter, and Mathematics*. Princeton, NJ: Princeton University Press.

Chaurasia, R. (2018). Ransomware: The Cyber Extortionist. In Z. Fields (Ed.), *Handbook of Research on Information and Cyber Security in the Fourth Industrial Revolution*. Hershey, PA: IGI Global. doi:10.4018/978-1-5225-4763-1.ch003

Christoff, K., Irving, Z. C., Fox, K. C., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature Reviews. Neuroscience*, *17*(11), 718–731. doi:10.1038/nrn.2016.113 PMID:27654862

Claridge, G. (Ed.). (1997). *Schizotypy: Implications for illness and health*. New York: Oxford University Press. doi:10.1093/med:psych/9780198523536.001.0001

Clegg, M. (2012). The Evolution of the Human Vocal Tract. In N. Bannan (Ed.), *Music, Language and Human Evolution*. Oxford, UK: Oxford University Press. doi:10.1093/acprof:osobl/9780199227341.003.0003

Coolidge, F. L., & Wynn, T. (2018). *The Rise of Homo sapiens: The Evolution of Modern Thinking* (2nd ed.). Oxford University Press.

Craft, A. (2005). *Creativity in Schools: Tensions and Dilemmas*. Routledge. doi:10.4324/9780203357965

Currie, G., & Ravenscroft, I. (2002). *Recreative Minds: Imagination in Philosophy and Psychology*. Oxford, UK: Clarendon Press. doi:10.1093/acprof:oso/9780198238089.001.0001

Curtis, D. (2004). Re-analysis of collaborative study on the genetics of alcoholism pedigrees suggests the presence of loci influencing novelty-seeking near D12S391 and D17S1299. *Psychiatric Genetics*, *14*(3), 151–155. doi:10.1097/00041444-200409000-00006 PMID:15318029

Darwin, C. (1859). *On the origin of species by means of natural selection, or, the preservation of favoured races in the struggle for life*. London: J. Murray.

Davies, G., Tenesa, A., Payton, A., Yang, J., Harris, S. E., Liewald, D., ... Deary, I. J. (2011). Genome-wide association studies establish that human intelligence is highly heritable and polygenic. *Molecular Psychiatry*, *16*(10), 996–1005. doi:10.1038/mp.2011.85 PMID:21826061

de Beaune, S. A. (2004). The invention of technology: Prehistory and cognition. *Current Anthropology*, *45*(2), 139–162. doi:10.1086/381045

Deacon, T. W. (1997). *The Symbolic Species*. New York: W. W. Norton.

Deary, I. J., Johnson, W., & Houlihan, L. M. (2009). Genetic foundations of human intelligence. *Human Genetics*, *126*(1), 215–232. doi:10.100700439-009-0655-4 PMID:19294424

Deary, I. J., Penke, L., & Johnson, W. (2010). The neuroscience of human intelligence differences. *Nature Reviews. Neuroscience*, *11*(3), 201–211. doi:10.1038/nrn2793 PMID:20145623

Dennett, D. (1976). Conditions of personhood. In A. Rorty (Ed.), *The identities of persons*. Berkeley, CA: University of California Press.

Desouza, K. C., Dombrowski, C., Awazu, Y., Baloh, P., Papagari, S., Jha, S., & Kim, J. Y. (2009). Crafting organizational innovation processes. Innovation: Management. *Policy & Practice*, *11*(1), 6–33. doi:10.5172/impp.453.11.1.6

Dick, D. M., Aliev, F., Bierut, L. J., Goate, A., Rice, J., Hinrichs, A., ... Hesselbrock, V. (2006). Linkage analysis of IQ in the collaborative study on the genetics of alcoholism (COGA) sample. *Behavior Genetics*, *36*(1), 77–86. doi:10.100710519-005-9009-8 PMID:16341907

Donald, M. (1991). *Origins of the modern mind: Three stages in the evolution of culture and cognition*. Cambridge, MA: Harvard University Press.

Dorsch, F. (2016). Knowledge by Imagination — How Imaginative Experience Can Ground Factual Knowledge. *Teorema: Revista Internacional De Filosofía*, *35*(3), 87-116. Retrieved from http://www.jstor.org/stable/44077413

Dunbar, R. (2004). *The Human Story*. London: Faber and Faber.

Durier, V., Graham, P., & Collett, T. S. (2003). Snapshot Memories and Landmark Guidance in Wood Ants. *Current Biology*, *13*(18), 1614–1618. doi:10.1016/j.cub.2003.08.024 PMID:13678592

Ebstein, R. P., Novick, O., Umansky, R., Priel, B., Osher, Y., Blaine, D., ... Belmaker, R. H. (1996). Dopamine D4 receptor (DRD4) exon III polymorphism associated with the human personality trait of novelty seeking. *Nature Genetics*, *12*(1), 78–80. doi:10.1038/ng0196-78 PMID:8528256

Edelman, G. (1987). *Neural Darwinism*. New York: Basic Books.

Edelman, G. (1989). *The remembered present: A biological theory of consciousness*. New York: Basic Books.

Edelman, G. (1999). Building a picture of the brain. *Annals of the New York Academy of Sciences*, *882*(1), 70. PMID:10415887

Edelman, G., & Tononi, G. (2000). *A universe of consciousness: How matter becomes imagination*. New York: Basic Books.

Eindhoven, J. E., & Vinacke, W. E. (1952). Creative processes in painting. *The Journal of General Psychology*, *47*(2), 165–179. doi:10.1080/00221309.1952.9710660

Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: A magnetic stimulation study. *Journal of Neurophysiology*, *73*(6), 2608–2611. doi:10.1152/jn.1995.73.6.2608 PMID:7666169

Faw, B. (1997). Outlining a Brain Model of Mental Imaging Abilities. *Neuroscience and Biobehavioral Reviews*, *21*(3), 283–288. doi:10.1016/S0149-7634(96)00026-7 PMID:9168264

Faw, B. (2009). Conflicting Intuitions May be Based on Differing Abilities: Evidence from Mental Imaging Research. *Journal of Consciousness Studies*, *16*(4), 45–68.

Filimon, F., Nelson, J. D., Hagler, D. J., & Sereno, M. I. (2007). Human cortical representations for reaching mirror neurons for execution, observation and imagery. *NeuroImage*, *37*(4), 1315–1328. doi:10.1016/j.neuroimage.2007.06.008 PMID:17689268

Finke, R. A. (1990). *Creative imagery: Discoveries and inventions in visualization*. Hillsdale, NJ: Erlbaum.

Finke, R. A., Pinker, S., & Farah, M. J. (1989). Reinterpreting visual patterns in mental imagery. *Cognitive Science*, *13*(1), 51–78. doi:10.120715516709cog1301_2

Gabora, L., & Kaufman, S. B. (2010). Evolutionary Approaches to Creativity. In J. C. Kaufman & R. J. Sternberg (Eds.), *The Cambridge Handbook of Creativity*. New York, NY: Cambridge University Press. doi:10.1017/CBO9780511763205.018

Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain*, *119*(2), 593–609. doi:10.1093/brain/119.2.593 PMID:8800951

Galton, F. (1880a). Statistics of Mental Imagery. *Mind*, *5*(19), 301–318. doi:10.1093/mind/os-V.19.301

Galton, F. (1880b). Visualized Numerals. *Nature*, *21*(533), 252–256. doi:10.1038/021252a0

Galton, F. (1880c). Mental Imagery. *Fortnightly Review*, *28*, 312–324.

Galton, F. (1883). *Inquiries into Human Faculty and its Development*. London: Macmillan. doi:10.1037/14178-000

Gaut, B. (2003). Creativity and Imagination. In B. Gaut & P. Livingston (Eds.), *The Creation of Art: New Essays in Philosophical Aesthetics*. Cambridge University Press.

Gerardin, E., Siriqu, A., Lehéricy, S., Poline, J. B., Gaymard, B., Marsault, C., & ... . (2000). Par- tially overlapping neural networks for real and imagined hand movements. *Cerebral Cortex*, *10*(11), 1093–1104. doi:10.1093/cercor/10.11.1093 PMID:11053230

Ghiselin, B. (1956). The creative process and its relation to the identification of creative talent. In C. W. Taylor (Ed.), *The 1955 University of Utah research conference on the identification of creative scientific talent*. Salt Lake City, UT: University of Utah Press.

Ghiselin, B. (1963). Automatism, intention, and autonomy in the novelist's production. *Daedalus*, *92*, 297–311.

Ghiselin, B. (Ed.). (1985). *The creative process: A symposium*. Berkeley, CA: University of California Press.

Golchert, J., Smallwood, J., Jefferies, E., Seli, P., Huntenburg, J. M., Liem, F., ... Margulies, D. S. (2016). Individual variation in intentionality in the mind-wandering state is reflected in the integration of the default-mode, fronto-parietal, and limbic networks. *NeuroImage*, *146*, 226–235. doi:10.1016/j.neuroimage.2016.11.025 PMID:27864082

Goodall, J. (1996). *The Chimpanzees of Gombe*. Cambridge, MA: Harvard University Press.

Goswami, A. (1996). Creativity and the quantum: A unified theory of creativity. *Creativity Research Journal*, *9*(1), 47–61. doi:10.120715326934crj0901_5

Gould, J. L. (1990). Honey Bee Cognition. *Cognition*, *37*(1-2), 83–103. doi:10.1016/0010-0277(90)90019-G PMID:2269009

Gould, S. J., & Vrba, E. S. (1982). Exaptation: A missing term in the science of form. *Paleobiology*, *8*(1), 4–15. doi:10.1017/S0094837300004310

Greogry, D. (2016). Imagination and mental imagery. In A. Kind (Ed.), *The Routledge Handbook of Philosophy of Imagination*. New York: Routledge.

Guilford, J. P. (1950). Creativity. *The American Psychologist*, *5*(9), 444–454. doi:10.1037/h0063487 PMID:14771441

Guilford, J. P. (1967). *The nature of human intelligence*. New York: McGraw-Hill.

Gusnard, D. A., Akbudak, E., Shulman, G. L., & Raichle, M. E. (2001). Medial prefrontal cortex and self-referential mental activity: Relation to a default mode of brain function. *Proceedings of the National Academy of Sciences of the United States of America*, *98*(7), 4259–4264. doi:10.1073/pnas.071043098 PMID:11259662

Hadamard, J. (1945). *An essay on the psychology of invention in the mathematical field*. Princeton, NJ: Princeton University Press.

Hampton, J. A. (1987). Inheritance of attributes in natural concept conjunctions. *Memory & Cognition*, *15*(1), 55–71. doi:10.3758/BF03197712 PMID:3821491

Hawkes, K., O'Connell, J. F., & Blurton-Jones, N. G. (1997). Hadza women's time allocation, offspring provisioning, and the evolution of long post-menopausal life-spans. *Current Anthropology*, *38*(4), 551–578. doi:10.1086/204646

Hebb, D. (1949). *The Organization of Behaviour: A Neuropsychological Theory*. New York, NY: John Wiley & Sons.

Hobson, P., Chidambi, G., & Meyer, J. (2006). Foundations for self- awareness: An exploration through autism. *Monographs of the Society for Research in Child Development*, *71*, vii-166. PMID:17177915

Hoen, A. (2017a). *Creative intelligence in Organizations – Insights for executives.* Retrieved from: https://veld.fm/creative-intelligence-in-organisations-e9eefb96068f

Hoen, A. (2017b). *How to use a heuristic to unlock creative intelligence and become more innovative*. Retrieved from: https://veld.fm/how-to-use-a-heuristic-to-unlock-creative-intelligence-and-become-more-innovative-fe069b0af28b

Howard-Jones, P. A., Blakemore, S. J., Samuel, E. A., Summers, I. R., & Claxton, G. (2005). Semantic divergence and creative story generation: An fMRI investigation. *Brain Research. Cognitive Brain Research*, *25*(1), 240–250. doi:10.1016/j.cogbrainres.2005.05.013 PMID:15993573

IBM. (n.d.). *The quest for AI creativity*. Retrieved from: https://www.ibm.com/watson/advantage-reports/future-of-artificial-intelligence/ai-creativity.html#section3

Jackson, P., Skirrow, P., & Hare, D. J. (2012). Asperger through the looking glass: An exploratory study of self-understanding in people with Asperger's syndrome. *Journal of Autism and Developmental Disorders*, *42*(5), 697–706. doi:10.100710803-011-1296-8 PMID:21647793

Jamison, K. (1989). Mood disorders and patterns of creativity in British writers and artists. *Psychiatry*, *52*(2), 125–134. doi:10.1080/00332747.1989.11024436 PMID:2734415

Jamison, K. R. (1993). *Touched with fire*. New York: Free Press.

Kant, I. (2006). *Anthropology from a Pragmatic Point of View* (R. Louden, Trans.). Cambridge, UK: Cambridge University Press.

Kaufman, A. B., Kornilov, S. A., Bristol, A. S., Tan, M., & Grigorenko, E. L. (2010). The neurobiological foundation of Creative Cognition. In J. C. Kaufman & R. J. Sternberg (Eds.), *The Cambridge Handbook of Creativity*. New York, NY: Cambridge University Press. doi:10.1017/CBO9780511763205.014

Kaufman, J. C., & Beghetto, R. A. (2009). Beyond Big and Little: The Four C Model of Creativity. *Review of General Psychology*, *13*(1), 1–12. doi:10.1037/a0013688

Kind, A. (2018). How imagination gives rise to knowledge. In M. Macpherson & F. Dorsch (Eds.), *Perceptual Imagination and Perceptual Memory*. Oxford, UK: Oxford University Press.

Kosslyn, S. M., Ganis, G., & Thompson, W. L. (2001). Neural foundations of imagery. *Nature Reviews. Neuroscience*, *2*(9), 635–642. doi:10.1038/35090055 PMID:11533731

Kosslyn, S. M., Ganis, G., & Thompson, W. L. (2001). Neural foundations of imagery. *Nature Reviews. Neuroscience*, *2*(9), 635–642. doi:10.1038/35090055 PMID:11533731

Kurzweil, R. (2005). *The Singularity is Near: When Humans Transcend Biology*. Viking Penguin.

Lakoff, G. (2014). Mapping the brain's metaphor circuitry: Metaphorical thought in everyday reason. *Frontiers in Human Neuroscience*, *8*.

Lakoff, G., & Johnson, M. (1980). *Metaphors We Live By*. Chicago: University of Chicago Press.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the Flesh*. New York: Basic Books.

Layman, T. (2010). *Build It and They Will Come*. Retrieved from <http://ngm.nationalgeographic.com/2010/07/bowerbirds/laman-photography>

Lerman, C., Audrain, J., Main, D., Bowman, E. D., Lockshin, B., Boyd, N. R., & Shields, P. G. (1999). Evidence suggesting the role of specific genetic factors in cigarette smoking. *Health Psychology*, *18*(1), 14–20. doi:10.1037/0278-6133.18.1.14 PMID:9925041

Leslie, A. M. (1987). Pretense and Representation: The Origins of "Theory of Mind". *Psychological Review*, *94*(4), 412–426. doi:10.1037/0033-295X.94.4.412

Levine, M. (1987). *Effective problem solving*. Englewood Cliffs, NJ: Prentice Hall.

Lubart, T. I. (2001). Models of the Creative Process: Past, Present and Future. *Creativity Research Journal*, *13*(3-4), 295–308. doi:10.1207/S15326934CRJ1334_07

Luciano, M., Wright, M. J., Duffy, D. L., Wainwright, M. A., Zhu, G., Evans, D. M., ... Martin, N. G. (2006). Genome-wide scan of IQ finds significant linkage to a quantitative trait locus on 2q. *Behavior Genetics*, *36*(1), 45–55. doi:10.100710519-005-9003-1 PMID:16341610

Mader, S. S., & Windespecht, M. (2016). *Biology* (12th ed.). New York: McGraw Hill Education.

Maeda, F., Kleiner-Fisman, G., & Pascual-Leone, A. (2002). Motor facilitation while observing hand actions: Specificity of the effect and role of observer's orientation. *Journal of Neurophysiology*, *87*(3), 1329–1335. doi:10.1152/jn.00773.2000 PMID:11877507

Maher, B. (1972). The language of schizophrenia: A review and interpretation. *The British Journal of Psychiatry*, *120*(554), 3–17. doi:10.1192/bjp.120.554.3 PMID:4557434

Marieb, E. N., & Hoehn, K. (2013). *Human Anatomy and Physiology* (9th ed.). Pearson Education.

Martindale, C. (1971). Degeneration, disinhibition, and genius. *Journal of the History of the Behavioral Sciences*, *7*(2), 177–182. doi:10.1002/1520-6696(197104)7:2<177::AID-JHBS2300070207>3.0.CO;2-N PMID:11609598

Martindale, C. (1977). Creativity, consciousness, and cortical arousal. *Journal of Altered States of Consciousness*, *3*(1), 69–87.

Martindale, C. (1989). Personality, situation and creativity. In J. Glover, R. Ronning, & C. Reynolds (Eds.), *Handbook of creativity*. New York: Plenum. doi:10.1007/978-1-4757-5356-1_13

Martindale, C. (1999). Biological basis of creativity. In R. J. Sternberg (Ed.), *Handbook of creativity*. Cambridge, UK: Cambridge University Press.

Mashal, N., Faust, M., Hendler, T., & Jung-Beeman, M. (2007). An fMRI investigation of the neural correlates underlying the processing of novel metaphoric expressions. *Brain and Language*, *100*(2), 115–126. doi:10.1016/j.bandl.2005.10.005 PMID:16290261

Mason, M. F., Norton, M. I., Van Horn, J. D., Wegner, D. M., Grafton, S. T., & Macrae, C. N. (2007). Wandering Minds: The Default Network and Stimulus-Independent Thought. *Science*, *315*(5810), 393–395. doi:10.1126cience.1131295 PMID:17234951

Matherne, S. (2016). Kant's theory of the imagination. In A. Kind (Ed.), *The Routledge Handbook of Philosophy of Imagination*. New York: Routledge.

McNamara, P., Nunn, C., Barton, R., Harris, E., & Capellini, I. (2007). Phylogeny of Sleep and Dreams. In D. Barrett & P. McNamara (Eds.), *The New Science of Dreaming* (Vol. 1). Westport, CT: Praeger.

Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review*, *69*(3), 220–232. doi:10.1037/h0048850 PMID:14472013

Mitchell, R. W. (2012). Self-Recognition in Animals. In M. R. Leary & J. Tangney (Eds.), *Handbook of Self and Identity* (2nd ed.). New York: Guilford Press.

Mithen, S. (1996). *The prehistory of the mind: The cognitive origins of art and science*. London, UK: Thames and Hudson.

Mithen, S. (2008). Seven Steps in the Evolution of the Human Imagination. In I. Roth (Ed.), *Imaginative Minds*. Oxford, UK: Oxford University Press.

Mithen, S. J. (2005). *The Singing Neanderthal: The Origins of Music, Language, Mind and Body*. London: Weidenfeld and Nicolson.

Modell, A. (2003). *Imagination and the meaningful brain*. Cambridge, MA: MIT Press. doi:10.7551/mitpress/3666.001.0001

Moss, R. (2015). *Creative AI: The robots that would be painters*. Retrieved from: https://newatlas.com/creative-ai-algorithmic-art-painting-fool-aaron/36106/

Neisser, U. (1967). *Cognitive psychology*. Englewood Cliffs, NJ: Prentice Hall.

Newell, A., & Simon, H. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice Hall.

Novitz, D. (1999). Creativity and constraint. *Australasian Journal of Philosophy*, *77*(1), 71–78. doi:10.1080/00048409912348811

O'Connell, J. F., Hawkes, K., & Blurton-Jones, N. G. (1999). Grandmothering and the evolution of Homo erectus. *Journal of Human Evolution*, *36*(5), 461–485. doi:10.1006/jhev.1998.0285 PMID:10222165

Ochse, R. (1990). *Before the gates of excellence: The determinants of creative genius*. New York: Cambridge University Press.

OpenStax. (2016). *The neuron*. Retrieved from Wikipedia wiki: https://commons.wikimedia.org/wiki/File:1206_The_Neuron.jpg

Osborn, A. (1953). *Applied Imagination*. New York: Charles Scribner.

Osborn, A. F. (1953). *Applied imagination*. New York: Scribners.

Patrick, C. (1935). Creative thought in poets. *Archives de Psychologie*, *178*, 1–74.

Patrick, C. (1937). Creative thought in artists. *The Journal of Psychology*, *4*(1), 35–73. doi:10.1080/00223980.1937.9917525

Patrick, C. (1938). Scientific thought. *The Journal of Psychology*, *5*(1), 55–83. doi:10.1080/00223980.1938.9917552

Patuzzo, S., Fiaschi, A., & Manganotti, P. (2003). Modulation of motor cortex excitability in the left hemisphere during action observation: A single and paired-pulse transcranial magnetic stimulation study of self- and non-self action observation. *Neuropsychologia*, *41*(9), 1272–1278. doi:10.1016/S0028-3932(02)00293-2 PMID:12753966

Polland, M. J. (1996). *Mental Imagery in Creative Problem Solving* (Doctoral Dissertation). Retrieved from https://files.eric.ed.gov/fulltext/ED393593.pdf

PricewaterhouseCoopers & World Economic Forum. (2017). *Fourth Industrial Revolution for the Earth: Harnessing the 4th Industrial Revolution for Sustainable Emerging Cities*. Retrieved from: https://www.pwc.com/gx/en/sustainability/assets/4ir-for-the-earth.pdf

Raichle, M. E. (2015). The brain's default mode network. *Annual Review of Neuroscience*, *38*(1), 433–447. doi:10.1146/annurev-neuro-071013-014030 PMID:25938726

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences of the United States of America*, *98*(2), 676–682. doi:10.1073/pnas.98.2.676 PMID:11209064

Rawlings, D., & Locarnini, A. (2008). Dimensional schizotypy, autism, and unusual word associations in artists and scientists. *Journal of Research in Personality*, *42*(2), 465–471. doi:10.1016/j.jrp.2007.06.005

Razumnikova, O. M., & Larina, E. N. (2005). Hemispheric interactions during the search for novel verbal analogies: Particularities of brain potentials' coherence in creative men and women. *I. P. Pavlov Journal of Higher Nervous Activity Names*, *55*(6), 785–795.

Richards, R. (Ed.). (2007). *Everyday creativity and new views of human nature: Psychological, social, and spiritual perspectives* (p. 349). Washington, DC: American Psychological Association. doi:10.1037/11595-000

Richards, R., Kinney, D. K., Lunde, I., Benet, M., & Merzel, A. P. C. (1988). Creativity in manic— Depressives, cyclothymes, their normal relatives, and control subjects. *Journal of Abnormal Psychology*, *97*(3), 281–288. doi:10.1037/0021-843X.97.3.281 PMID:3192819

Rizzolatti, G., & Craighero, L. (2004). The Mirror-Neuron System. *Annual Review of Neuroscience*, *27*(1), 169–192. doi:10.1146/annurev.neuro.27.070203.144230 PMID:15217330

Rizzolatti, G., Fabbri-Destro, M., & Cattaneo, L. (2009). Mirror neurons and their clinical relevance. *Nature Clinical Practice. Neurology*, *5*(1), 24–34. doi:10.1038/ncpneuro0990 PMID:19129788

Rodriguez, J. (2016). *AI and the Human Brain: Creativity and Imagination*. Retrieved from: https://medium.com/@jrodthoughts/ai-and-the-human-brain-creativity-and-imagination-56ca99198d06

Roe, B. E., Tilley, M. R., Gu, H. H., Beversdorf, D. Q., Sadee, W., Haab, T. C., & Papp, A. C. (2009). Financial and psychological risk attitudes associated with two single nucleotide polymorphisms in the nicotine receptor (CHRNA4) gene. *PLoS One*, *4*(8), e6704. doi:10.1371/journal.pone.0006704 PMID:19693267

Rossman, J. (1931). *The psychology of the inventor*. Washington, DC: Inventors Publishing.

Runco, M. A. (2004). Everyone has creative potential. In R. J. Sternberg, E. L. Grigorenko, & J. L. Singer (Eds.), *Creativity: From potential to realization*. Washington, DC: American Psychological Association. doi:10.1037/10692-002

Ryle, G. (1949). *The Concept of Mind*. New York: Barnes & Noble.

SAKAN. (n.d.). *South Africa's Fourth Industrial Revolution*. Retrieved from: http://www.sakan.org.za/4IR.html

Semaw, S., Renne, P., Harris, J. W. K., Feibel, C. S., Bernor, R. L., Fesseha, N., & Mowbray, K. (1997). 2.5-million-year-old stone tools from Gona, Ethiopia. *Nature*, *385*(6614), 333–336. doi:10.1038/385333a0 PMID:9002516

Sepper, D. L. (2016). Descartes. In A. Kind (Ed.), *The Routledge Handbook of Philosophy of Imagination*. New York: Routledge.

Smith, S. M. (1995a). Fixation, incubation, and insight in memory and creative thinking. In S. M. Smith, T. M. Ward, & R. A. Finke (Eds.), *The creative cognition approach*. Cambridge, MA: MIT Press.

Smith, S. M. (1995b). Getting into and out of mental ruts: A theory of fixation, incubation, and insight. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight*. Cambridge, MA: MIT Press.

Soler, M., Pérez-Contreras, T., & Peralta-Sánchez, J. M. (2014, January 27). Mirror-Mark Tests Performed on Jackdaws Reveal Potential Methodological Problems in the Use of Stickers in Avian Mark-Test Studies. *PLoS One*, *9*(1), e86193. doi:10.1371/journal.pone.0086193 PMID:24475085

Spreng, R. N., & Schacter, D. L. (2012). Default network modulation and large-scale network interactivity in healthy young and old adults. *Cerebral Cortex*, *22*(11), 2610–2621. doi:10.1093/cercor/bhr339 PMID:22128194

Stein, M. I. (1974). *Stimulating creativity: Individual procedures*. New York: Academic.

Takenaka, H. (2018). *Making Japan a major force in the Fourth Industrial Revolution*. Retrieved from: https://www.japantimes.co.jp/opinion/2018/04/02/commentary/japan-commentary/making-japan-major-force-fourth-industrial-revolution/#.XL8A2JgzbIV

Taylor, I. A. (1959). The nature of the creative process. In P. Smith (Ed.), *Creativity: An examination of the creative process*. New York: Hastings House.

Taylor, I. A., Austin, G. A., & Sutton, D. F. (1974). A note on "instant creativity" at CPSI. *The Journal of Creative Behavior*, *8*(3), 208–210. doi:10.1002/j.2162-6057.1974.tb01126.x

Tesla, N. (1919). *The Autobiography of Nikola Tesla*. New York, NY: Experimenter Publishing Company, Inc.

Thompson, A. L., & Klatzky, R. L. (1978). Studies of visual synthesis: Integration of fragments into forms. *Journal of Experimental Psychology. Human Perception and Performance*, *4*(2), 244–263. doi:10.1037/0096-1523.4.2.244 PMID:660099

Vanderah, T., & Gould-Nolte, D. (2015). *Nolte's The Human Brain: An Introduction to its Functional Anatomy* (7th ed.). Philadelphia, PA: Elsevier.

Vinacke, W. E. (1952). *The psychology of thinking*. New York: McGraw-Hill.

Visalberghi, E., & Fragaszy, D. (2001). Do monkeys ape? Ten years after. In K. Dautenhahn & C. Nehaniv (Eds.), *Imitation in Animals and Artifacts*. Boston, MA: MIT Press.

Wallas, G. (1926). *The art of thought*. New York: Harcourt Brace.

Walton, K. L. (1990). *Mimesis as Make-Believe: On the Foundations of the Representational Arts*. Cambridge, MA: Harvard University Press.

Wehner, R., & Menzel, R. (1990). Do Insects have Cognitive Maps? *Annual Review of Neuroscience*, *13*(1), 403–414. doi:10.1146/annurev.ne.13.030190.002155 PMID:2183682

Weisberg, R. W. (1986). *Creativity: Genius and other myths*. New York: Freeman.

White, A. R. (1990). *The Language of Imagination*. Oxford, UK: Basil Blackwell.

Whiten, A., & Suddendorf, T. (2008). Great Ape Cognition and the Evolutionary Roots of Human Imagination. In I. Roth (Ed.), *Imaginative Minds*. Oxford, UK: Oxford University Press.

Wittgenstein, L. (1958). *Philosophical Investigations* (2nd ed.; G. E. M. Anscombe, Trans.). Basil Blackwell.

World Economic Forum. (2016). The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution. *Global Challenge Insight Report*. Retrieved from: http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf

World Economic Forum & Asian Development Bank. (2017). *ASEAN 4.0: What does the Fourth Industrial Revolution mean for regional economic integration?* Retrieved from: http://www3.weforum.org/docs/WEF_2017_ASEAN%204IR.pdf

Zabelina, D. L., & Andrews-Hanna, J. R. (2016). Dynamic network interactions supporting internally-oriented cognition. *Current Opinion in Neurobiology*, *40*, 86–93. doi:10.1016/j.conb.2016.06.014 PMID:27420377

ADDITIONAL READING

Boden, M. A. (2006). *Mind as machine: A history of cognitive science*. Oxford: Clarendon Press.

Edelman, G. (1987). *Neural Darwinism*. New York: Basic Books.

Kaufman, J. C., & Sternberg, R. J. (Eds.), *The Cambridge Handbook of Creativity*. New York, NY: Cambridge University Press.

Kind, A. (Ed.), *The Routledge Handbook of Philosophy of Imagination*. New York: Routledge.

Kurzweil, R. (2005). *The Singularity is Near: When Humans Transcend Biology*. USA: Viking Penguin.

Mader, S. S., & Windespecht, M. (2016). *Biology* (12th ed.). New York, NY: McGraw Hill Education.

Marieb, E. N., & Hoehn, K. (2013). *Human Anatomy and Physiology* (9th ed.). USA: Pearson Education.

Modell, A. (2003). *Imagination and the meaningful brain*. Cambridge, MA: MIT Press. doi:10.7551/mitpress/3666.001.0001

Polland, M. J. (1996). *Mental Imagery in Creative Problem Solving (Doctoral Dissertation)*. Retrieved from https://files.eric.ed.gov/fulltext/ED393593.pdf

Vanderah, T., & Gould-Nolte, D. (2015). *Nolte's The Human Brain: An Introduction to its Functional Anatomy* (7th ed.). Philadelphia, PA: Elsevier.

Vartanian, O., Bristol, A. S., & Kaufman, J. C. (Eds.), *Neuroscience of Creativity*. Cambridge, MA: MIT Press.

KEY TERMS AND DEFINITIONS

4IR: Is the ensuing era of computing, with the amalgamation of emergent technologies like cognitive and machine learning, artificial intelligence, internet of things, wearable technology, biotechnology, 3D printing, smart cities, etc. to create a smart world where everything communicates with everything else intelligently, with the purpose of achieving the unthinkable.

Creativity: Is the process of generation of novel ideas, that bear some value or significance in a wider context, that requires expert knowledge, practice and skill in the field in which the creative ideas are shaped. Imagination plays a major role in the generation such ideas.

Default Mode Network: Consists of the medial temporal, posterior cingulate cortex, medial praecuneus, inferior parietal and prefrontal regions of the brain and remains active during the brain's resting state as well as during cognitive tasks such as daydreaming, mind-wandering, anticipation of the future, self-referential judgements, etc.

Imagery: Is a process of creating mental images that helps us to form memories, retain information for future recall, think and reason about objects not present in the visual field.

Imagination: Is the process of forming mental images of what is not actually present to the senses. It also allows anticipating the outcome of an action without actually performing it via simulation and plays a significant role in visionary and creative thought.

Imagination Age: A new era beyond the information age, where creativity and imagination are gaining momentum as the major originators of economic importance.

Innovation: Is the process of executing these novel ideas to create a new product or implementing that idea in some way.

Mirror Neurons: Are a class of visuomotor neurons found in the human brain's motor cortex, that fires both in the presence of meaningless intransitive movements and movements forming an action.

Neurons: Are a functional unit of the nervous system and differ in appearance depending on their function and location that consist of three major components – a cell body (soma), an axon, and dendrites.

Chapter 2
The Imaginary Structure of the Fourth Industrial Revolution

Thomas Michaud
CNAM, France

ABSTRACT

Science fiction is increasingly involved in innovation processes in technological sectors. The imaginary, through design fiction, stimulates the creativity of decision makers and engineers who work to create a better world through technoscience. Science fiction participates in global innovation by constructing sectoral myths and by proposing a new form of rationality integrating the technical imaginary. Imaginnovation is a neologism, a synthesis of the terms imagination and innovation. This practice, already developed in several companies and organizations, will guide the decision-making process during the next industrial revolution. Science fiction appeared more than 200 years ago, when technical progress profoundly changed society. It later became an integral dimension of collective psychology. Its critical dimension must also be considered as a structuring element of the contemporary technical imagination. Innovation realizes imagination and science fiction allows the productive system to access the unconscious fantasies of individuals and social groups.

SUMMARY

Science fiction is increasingly involved in innovation processes in technological sectors. Industries of computing, virtual reality, biotechnology, space exploration and climate control are part of the fourth industrial revolution. The imaginary, through design fiction, stimulates the creativity of decision-makers and engineers

DOI: 10.4018/978-1-5225-9188-7.ch002

who work to create a better world through technoscience. Science fiction participates in global innovation by constructing sectoral myths and by proposing a new form of rationality integrating the technical imaginary. *Imaginnovation* is a neologism, a synthesis of the terms imagination and innovation. This practice, already developed in several companies and organizations, will guide the decision-making process and the design of new products during the next industrial revolution. Science fiction appeared more than 200 years ago, when technical progress profoundly changed society. It later became an integral dimension of collective psychology. Its critical dimension must also be considered as a structuring element of the contemporary technical imagination. Innovation realizes imagination and science fiction allows the productive system to access the unconscious fantasies of individuals and social groups.

INTRODUCTION

This article looks at the impact of science fiction in the management of the fourth industrial revolution. Multiple technologies are presented as the elements of a major change in the global economy in the coming years. Most of them have been described in imaginary narratives, the oldest of which date back to the nineteenth century. Each technology announced as revolutionary will be the subject of an analysis of its imaginary representations (Alkon, 2002, 2010). The question will be whether science fiction anticipates scientific discoveries and technical progress. Better still, it will be suggested that economic cycles and industrial revolutions are stimulated by imaginaries often under-considered by the actors of innovation processes. Virtual reality, nanotechnologies, biotechnologies, cognitive sciences, the space sector, and many others are brought to radically change society. The fear of destructive automation of employment is a speech that often appears at the beginning of a new period of innovation. Technophobies and technological utopias find an ideal field of expression in science fiction. With the 4th industrial revolution, a new use of science fiction appears. Now, the most innovative companies are creating their own science fiction. They study the imaginary to develop their strategic visions, which must be mobilizing for their employees, but also for future clients. The next industrial revolution is already perceived as one that will achieve science fiction. Producing fiction is a necessity to maintain leadership in certain technological sectors such as ICT.

But science fiction also raises fears of the population vis-à-vis a techno-scientific sphere that could generate monstrosities if it was not controlled by citizens (Brake, 2008). The Frankenstein syndrome is constantly coming back to give a critical dimension to this imaginary. Some actors regret that this imaginary is developed in a capitalistic perspective, while others are enthusiastic about living in a world of science fiction realized.

This article will present at first some examples of science fiction works announcing or accompanying innovations in five sectors of the 4th industrial revolution. Then, it will focus on the mutations of this imaginary that has become a very influential imaginary matrix in the economics and evolution of techno-sciences. A question will be asked in this article: is the use of science fiction to innovate and manage compatible with ethical limits set by society? Can the 4th industrial revolution use the imaginary as a techno-political program, at the risk of sinking into a form of ultra-scientism potentially dangerous for humanity?

At first, a presentation of the utopian technologies relating to the 4th industrial revolution is necessary. Science fiction has the reputation of anticipating innovations since the nineteenth century (Disch, 2000). What are the relations between this imagination and the creativity of scientists and engineers? To what extent is the imaginary an engine for decision-makers, strategists and innovators? Capitalism seems to evolve by realizing fantasies of science fiction. Economic cycles are thus marked, at different levels, by a relation of innovation policies with imaginary technologies. The imaginary and the unconscious are important actors of the global economic system. Science fiction imagines possible futures that end up constituting a collective imagination unifying innovation policies all over the planet. Seeking to achieve utopian technologies unites the research and development teams (Dregni, 2006). On all continents, new paradigms, such as the Fourth Industrial Revolution, are the result of multiple imaginaries that interconnect and generate models of future societies. Business planning and strategy must take into account imaginary processes to offer consumers products that fit into unified representations of the future, and for some, become true sectoral myths that are useful for the overall management of innovation.

The Imaginary of Some Announced Innovations

The Future of the Internet and Virtual Reality

Internet and Artificial Intelligence will be at the center of the next industrial revolution (Marcus, 1995). The proliferation of futuristic discourses that have accompanied the development of computers and networks has helped to structure technophilia. Since William Gibson, the concept of cyberspace is a utopian technology that has inspired many science fiction writers and engineers in the ICT sector (Michaud, 2008). Immersive virtual reality is a Grail for inventors since the 1980s, and a subject of many movies and novels. Fictions are technophile or technophobic, and help to structure the public debate on the future of networks. Science fiction has shown in dozens of works virtual technologies that fall into the wrong hands and cause disasters. The announced fusion of artificial intelligence and virtual realty could, according to the futurist authors, leak towards cyberspace or metaverses provoking a derealization of the subject (Bukatman, 1993).

The book *La réalité virtuelle, de la science-fiction à l'innovation* (2018), is based on the study of some fifty science-fiction works whose central theme is virtual reality. Often futuristic, these stories have an impact on the innovation process in the virtual sector. *Neuromancer*, *Snow Crash*, *Permutation City* and *The Matrix* are the 4 best known fictions of virtualist science fiction. Other films and novels are studied and analyzed in order to elaborate a theory on the genesis and the functioning of the technical imagination. The latter is presented as an important variable in the innovation process. The approaches of leading thinkers of social sciences such as Durand, Jung or Campbell put into perspective the function of the myth in industrial societies.

Representations of the future of virtual reality evolve as technical progress achieves and even surpasses the imaginary. *Sword Art Online*, *Accel World*, *Next Level*, *The Age of Satisfactor*, *Inner City*, *Virtual Revolution*, *Rewind*, *Tron* and *Tron, Legacy*, *Mind Games*, or *Otherlife* are some examples of works more or less known that participate in the construction of a collective imagination favorable to innovation in the field of virtual reality. The book *Ready Player One*, by Ernest Cline, also plays an important role in this book which could be integrated in more global research on the imagination of the engineers, but also on the impact of these representations in the construction of strategies of innovators and managers. It is interesting to note that most of the major innovations related to the virtual and the Internet have appeared in motor-driven territories in the technical imaginary sector, such as the United States and Japan.

The book is based on a presentation of the imaginary of the virtual to develop a theory of technotypes. These psychic elements can be defined as the synthesis of fundamental archetypes theorized by Jung and present in the collective unconscious, and utopian, innovative technologies. One of the questions posed by this study is the following: is there a global imaginary shared by all humans, or does the imaginary appear at the individual level? Research on innovation has an interest in finding answers to this question in order to determine the processes of emergence of the imagination. In this way, it is possible to stimulate the technical imagination through science fiction in organizations. To look for the technotypes constitutes a stake at first scientific, but also strategic, the control of the technical imagination leading the main actors of capitalism to propose first the most innovative technologies.

A Space Revolution

The conquest of space could enter a new era with private investments increasingly important. Billionaires like Richard Branson, Elon Musk and Jeff Bezos have paved the way for space tourism and the colonization of the Moon and Mars. These leaders and pioneers have been influenced by science fiction and have invested a portion of their personal fortune to develop ships capable of equaling or exceeding the performance of space agencies such as NASA or ESA. The space dream has been built for 150 years partly in the imagination and in science fiction. Jules Verne is a prophet because of his prefiguration of the Apollo mission in his novel *From Earth to the Moon*. The space conquest was later represented in films with great commercial success (De Witt, 2003). The movie *2001, a Space Odyssey* had a considerable impact on the collective imagination. Humanity could imagine its spatial future (McCurdy, 1995). Films like *Armageddon* have also introduced important issues for the survival of humanity in the universe. The fear of percussion with an asteroid mobilizes teams of researchers more and more worried about this danger. Asteroids also attract the greed of some states and private actors, motivated by the desire to exploit their potentially huge mineral resources. Several actors in the space sector are developing technologies capable of deflecting the trajectory of an asteroid, either to keep it off the Earth's path, or to direct it to bases capable of exploiting it. They regularly post on the Internet videos about the future of these technologies. These short films are very much like science fiction and aim to convince investors. Investing in futuristic projects is an important motivation for more and more actors. After sustainable development, the construction of a multi-planetary human civilization is no longer pure speculation. This is a sci-fi scenario increasingly credible. Colonizing Mars has been the subject of many films, often dystopian, but sometimes dreamlike. The film *The Martian* met with great success because of its realism. An astronaut given for dead and abandoned by his team on Mars had to organize himself to survive thanks to his scientific and technical knowledge. This type of story is highly motivating young people to engage in scientific careers. But science fiction also has a role in shaping the strategic discourse of organizations. Behavioral economics must take into account the growing role of the imaginary in the construction of mobilizing discourses of companies and institutions.

Biotechnology and the Search for Immortality

Biotechnology is at the heart of the ambitions of the fourth industrial revolution. Developing the knowledge of genetics, artificial life, and medicine is part of the quest for immortality. Thanks to the accumulation of data, it will be possible to know patients better, and to develop more complex researches, taking into account data related to societal and cultural factors which could be the cause and consequence of certain pathologies. Science fiction has imagined since the 1980s the spread of nano-robots in the human body to prevent many pathologies. Networking of medical data poses ethical, individual data protection issues, but this practice could lead to significant progress and the discovery of new treatments. The fusion of biotechnologies and ICTs is one of the industrial issues of the coming years. It could lead to the creation of drugs that, for example, make possible to create more resistant beings, for example adapted to environments previously hostile to humanity, such as extraterrestrial worlds. Science fiction has since *Frankenstein* largely treated this subject. Medicine could make considerable progress useful to the progress of humanity. Science fiction has the function of pointing out possible ethical drifts in order to alert public opinion of the latest experiences of researchers often represented like mad scientists. .

In *Man Plus*, Frederik Pohl wonders about the monstrous dimension of a surgically modified astronaut in order to become the first Martian. Does the question of the adaptation of human beings in space have any limits? Are medicine and science subject to political or even military imperatives? In the novel, several guinea pigs die before one of them is implantable on Mars. The President of the United States expresses a strong voluntarism, aware that his power is conditioned by the success of a Martian mission. The human being is radically altered to serve a Martian political purpose. The Man Plus project is crucial at the political level because it must allow the democratic countries of the free world to territorialize the planet Mars. Means do not count. Only the finality is to remember. Cyborgs are presented as monsters in this novel which raises many ethical questions to a concept invented in the 1960s to create a modified human adapted to the conquest of space. Such experiments have not officially taken place, and the concept of space cyborg is not relevant for several decades. It would be surprising if the population accepts from its rulers such experiments for the sole purpose of colonizing other planets. Unless important geostrategic issues emerge and the creation of such monstrous beings becomes a necessity.

The Transport Sector

The transport sector will be revolutionized by several major innovations. However, they will only be one step before the abolition of any form of pollution through teleportation. This technology is a *sectorial myth* imagined in *Star Trek*, and would avoid all forms of travel by polluting devices. In addition, the instantaneity enabled by this technology would provide considerable time savings. Video telephony and telepresence have been rapidly diffused in the 2010s, and the optimization of this technology could already provide a considerable advance for humanity in the next decades, before the advent of teleportation, Grail of telecommunications and transport of the future.

Weather Control

Global warming is a major issue for the next industrial revolution. The ideal would be to create a technology capable of controlling the climate. This demiurgic dream probably appeared among the first men endowed with a rational mind. Science fiction has imagined since the beginning of the industrial revolution such a machine and the consequences it would have on geopolitics. Samuel Johnson was a precursor of this theme in *Rassek (*1789), and Jane Loudon felt that such an invention could be conceived in several centuries in *The Mummy* (1827). A long series of science fiction novels tackled this subject, which has taken another dimension since the 2000s with the appearance of a new global challenge, the management of global warming. The most powerful technologies can not do anything against the forces of nature. Storms and climate disruption could eradicate any form of civilization. The film *Geostorm* (2017) addresses this theme. Humans, faced with the disastrous consequences of global warming, must come together to develop a satellite network that can regulate the climate. However, the machine begins to go wrong, which causes new disasters. The heroes realize that the machine is controlled by people wanting to return it against its creators, generating a geostorm, a global storm that would destroy millions of humans and allow survivors to control the world. In the short term, regulating global warming must allow humanity to survive. In the longer term, this technoscience could make possible to modify the climates of other planets to facilitate the implantation of human colonies. Tests could be done on Mars, where the most audacious scenarios suggest that terraforming will be possible in the future.

Imaginnovation, Discursive Matrix of the 4th Industrial Revolution

Economic history shows that the industrial revolution begun in the eighteenth century was based on fundamental discoveries, without it being possible to associate them with works of fiction that could have inspired the discoverers. Yet science fiction appeared soon after, and helped shape Western enthusiasm for science and technical progress. It was in the late nineteenth century and early twentieth century that science fiction began to influence the actors of capitalism, with increasingly influential publications by authors such as Jules Verne or Hugo Gernsback (Westfahl, 1998).

The concept of imaginnovation is useful for describing the conditions of propagation of innovative ideas in an ultra-technological society. With the fourth industrial revolution, capitalism has reached a form of maturity that allows it to consciously use the imaginary, to plan the processes of innovation conceived as useful means to realize the imaginary. Walt Disney had conceived the concept of imagineering in 1952, that is to say a method for imagining new activities in leisure parks. Imaginnovation is based on the premise that the imagination is an important engine for innovation. In addition to sometimes proposing utopian technologies that inspire some researchers, the imaginary humanizes technoscience by addressing social, political or environmental aspects. Designing the future is also imagining the applications of innovations still in the state of prototypes. How does imaginnovation work? This managerial practice is about to conquer the creativity sessions of the big companies, as well as the R&D centers all over the planet. More than innovate, we must show the most sophisticated imagination possible to conquer markets and seduce consumers. Achieving science fiction becomes a must for innovators. Customers are increasingly bathed in an imaginary world made up of stories in which the future is governed by still purely imaginary technologies. Since the 1980s, innovation has been growing rapidly, and business cycles have followed one another with inventions, some of which, such as the Internet or mobile phones, have revolutionized society. Science fiction may not have anticipated the Internet, as many critical minds have pointed out, doubting the prophetic function of this art (Scholes, 1994). But fictions since the 1980s have seized computerization and the networked society to imagine what these innovations will become, as well as their impact on society and people's lifestyles. Science fiction has seized on the subject of the future of ICTs and has come to accompany the most fundamental innovations, becoming in a few decades a discursive matrix both popular and elitist. Customers love the science fiction aesthetic and the feeling of living in a science fiction universe. Strategists also often have a good fictional science culture that guides their decisions and investments in R&D projects (Michaud, 2011).

Imaginnovation is a practice close to sf prototyping and fiction design, terms used to describe the use of science fiction to innovate and find new outlets for innovators.

Imaginnovation is interested in using the technical imaginary from science fiction to innovate in private or public R&D centers. The use of design fiction has emerged in recent years as a strategic necessity (Barbrook, 2007). Thinking about the future involves the use of artists, designers and science fiction writers. This presupposes an interest in the status of technical fiction in the patentability process of an invention. Hugo Gernsback, the founding father of science fiction, thought that a patent system for imaginary technologies in movies and novels was needed, so that the global innovation process would recognize the influence of these stories considered as sources of inspiration at the origin of many innovations generating for some considerable income for companies. This reflection aims to answer the question of the anticipatory, even prophetic, function of science fiction, and its extension, design fiction. To prove that fiction anticipates technical and scientific thought, it would be necessary to patent utopian technologies. If these are actually realized and paid for their authors, proof will be made of the prophetic dimension of science fiction. If, on the other hand, it is not proven that utopian technologies end up being realized by inspiring researchers and engineers, the myth of a prophetic science fiction will collapse.

Imaginnovation comes down to considering that imagination is at the forefront of scientific and technical discoveries. Fiction is seen as a primordial state of all research and discovery. It is important, however, to avoid considering fiction as a prophecy, in order to avoid superstitions and skepticism harmful to science. The anticipatory function of science fiction, however, is conceived in more and more publications as the origin of many innovations of the last 30 years. It may be a coincidence, or an ideological conception of the history of technology. But with imaginnovation, imagining it is streamlined, managed and created as an important step in the innovation process. Imagination becomes an important asset for organizations, which use science fiction writers and artists to develop fictions for designers of new concepts and products. Will the fourth Industrial Revolution create the desired patent system by Gernsback ? It seems that most major powers agree on the virtues of science fiction to innovate (Buderi, 2000). The coming to power of high and educated generations with this imaginary augurs the advent of practices more and more daring and creative (Davis, 2015).

Design Fiction and the use of Science Fiction in Large Companies

A new practice called design fiction contributes since the beginning of 2010 to structure the imagination of R&D centers in the most industrialized countries (Johnson, 2011). Thinking the future through the prism of science fiction has become an increasingly popular practice for harnessing and stimulating the imagination of actors in innovation processes. The imaginary was for a long time considered as a harmful faculty because subversive, dangerous for the legitimate power. Then, it was assimilated to a childish practice, proof of the immaturity of its followers. Worse, some actors felt that an uncontrolled use of the imaginary was the proof of a psychic dysfunction. The philosopher Fontenelle also criticized people who made the profession of the imagination of the future, the latter being considered dangerous for the all-powerful Christian Church. Criticism of the imaginary is now extremely rare. More and more players believe that it must be developed because it is a source of creativity and innovation. Inventors are presented as spirits capable of concretizing their imagination in new theories or technical processes for certain revolutionaries. Design fiction is the result of a collective awareness of the interest of science fiction to innovate. It appeared in the Anglo-Saxon countries and could influence the management and the sessions of creativity in the next years and decades. Economic cycles are associated with cycles of imaginary representations. An industrial revolution is thus the product and the starting point of technical imaginary whose operation will be presented. Initially, the imaginary unveils to actors or groups of actors visions of new technologies, in keeping with already mature technologies and disseminated in society. The desire to create imaginary technologies is the starting point of the motivation of inventors. The actor who designs a utopian technology may decide not to disclose it in an attempt to develop it in secret. This corresponds to a romantic approach to innovation. Capitalism encourages these people to share their visions in order to allow others, complementary skills, to insert them into industrial processes leading to experiments, prototypes, and sometimes to innovations, some of which will be commercially successful (Shedroff, 2012).

In this process, capitalism gives an important place to science fiction, conceived as a medium capable of capturing and crystallizing in the form of imaginary narratives of utopian technologies (Michaud, 2017). Science fiction works as an attractor and receptacle of imaginary concepts which, if they are instrumentalized by the technical system, can be useful to innovators. Design fiction is based on the observation that imagination is at the forefront of many innovations in the history of the industrial revolution and proposes to industrialize the technical imagination. As a first step, major Hollywood productions and science fiction novels must be studied in the form of a strategic watch to assess the interesting prospects for the economic sector of the company or institution that finances this approach. The mapping of the technical imaginary is a first step which makes it possible, in particular, to detect sectoral myths, that is to say fictions collectively shared globally and which consciously and unconsciously influence research in competing firms in the short term and finally partners in the medium and long term. The myth of terraforming of Kim Stanley Robinson, the laws of robotics of Asimov or Gibson's cyberspace are industry myths that guide the research of thousands of engineers scattered around the globe. In another time, the industry must create its own imaginary, stimulate its engineers, which leads to use science fiction prototyping and design fiction. It is difficult to obtain fiction produced by the R&D centers of large companies because they have an important strategic and symbolic value. The latter, however, occasionally broadcast small commercials from their prospective services. Thousands of these works are on the Internet, the first of which date back to the 1950s. Science fiction contests are organized internally or open to a wider audience. It is not uncommon for American companies to use science-fiction writers to develop their representations of the future and to design a foresight useful for the construction of a performative strategic discourse (Parker, 1992).

Science Fiction, a Critique of Technical Progress?

Science fiction is also a useful art for social criticism. While many imaginary technologies have emerged and are a specificity of these stories, many authors believe that their stories are part of a questioning of potentially liberticidal applications of innovations in research and development centers. A large number of dystopian narratives are part of the continuity of the novel *1984* (Aldridge, 1984) Science-fiction frequently describes totalitarian societies, in which power is often won thanks to the Machiavellian use of technology. The *Black Mirror* series thus raises the question of the liberticidal dimension of certain communication technologies that will be at the center of the fourth industrial revolution. This program offers stories that often end badly, pushing at the most critical, sometimes paranoid, reflection on the fate of seemingly positive innovations that generate nightmarish situations. Science fiction offers thought experiments whose purpose is not the realization of negative worlds, but on the contrary to develop an ethic in order to prevent the quest for profit from provoking an immoral, authoritarian, even totalitarian social organization. ICTs have significant potential for harm, as are any technology. Large companies and state institutions must be inspired by scientific-fictional criticism to avoid drift and be part of a positive approach, sustainable development. It is also fundamental for the dominant systems to maintain their technological leadership in order to prevent competing, temporarily inferior and dominated systems from developing innovative technologies that allow them to develop power that potentially serves negative moral values. Science fiction is therefore fascinated by technical progress and scientific research, but also develops a critical reflection of its consequences for individual and collective freedoms.

Can the fourth industrial revolution generate a dystopian society because of a negative dominant technical imaginary? Many science fiction writers, including Neal Stephenson, are surprised by the large number of dystopias in recent years. Science-fiction seems to have become incapable of proposing technological utopias, to fulfill the function of the utopianism of which the American historian Howard Segal has shown that it constituted since the nineteenth century an important element of the dynamics of techno-scientific capitalism. Science fiction can also criticize class struggle from Fritz Lang's *Metropolis* and *The Time Machine* of Wells. Will the fourth industrial revolution use innovations to create a fairer, more egalitarian society, or will its innovations serve tyrants? Thinking about the future of this major change involves extrapolating imaginary scenarios. The film *Elysium* is an example of social criticism in a future fundamentally unequal society. It takes place in 2154. Humanity is divided into two classes. The rich live in a space station where they can stay young and healthy for many years. On Earth, poverty and pollution make living conditions very difficult. The inhabitants of Elysium, the name of the space colony, benefit in particular from a Med Box, capable of curing all diseases in a few seconds, for example by a process of re-atomization. The leaders of Esylium protect their privileges eagerly and do not hesitate to shoot down the space shuttles filled with poor earthlings victims of incurable diseases and trying to ultimately hope to access a Med Box. The hero works in a factory, at the chain, and is the victim of exposure to radiation, which condemns him to die in 5 days. His ultimate hope is to rally Elysium. He must also help a young leukemia to access a Med Box. The film tells how the poor are trying to access a high-level medicine that can cure all diseases. By a combination of circumstances and struggles that would be too long to recall here, a new social class seizes Elysium, which changes the balance of power. The technology of the Med Box is then directed towards an earth population victim until then of diseases.

The film explains that the Earth is overpopulated, which implies a specific population management, and the refusal to spread medical technologies to the greatest number. This fountain of youth of the technocientific era is reserved for an elite, who does not wish to share it. Science fiction allows a forward thinking about the consequences of innovations on society and raises the question of the use of medicine in the world today. Is it possible to disseminate the most advanced medical technologies to the lower social classes and the poorest people? Should rich countries share their knowledge with poor countries, under pain of exposing themselves to revolts and eventually to their annihilation? The film poses a cruel dilemma. On the one hand, is it not suicidal to increase the life expectancy of a humanity that is already too large? On the other hand, is refusing to broadcast Med Boxes and medical innovations ethical and sustainable for the elite? The management of overcrowding is a theme often tackled by science fiction. The film *Seven Sisters* evokes the limitation to one birth per woman. Other births are cremated. Medicine is thus challenged in this type of society, its healing power being unsuited to the need to manage the shortage of space and food.

Imaginary and Behavioral Economics

Behavioral economics seeks to understand the psychological mechanisms of economic attitudes. Imagination plays an important role in innovation processes at the global level. It helps to structure collective visions of the future. For that, it must be interpreted, formatted, in order to reach the widest possible population. Hollywood is a powerful player in calibrating a global collective imagination that, without normalizing systems, would remain ineffective, insignificant. Industrial revolutions are based on flagship technologies that appeal to the markets and are at the center of managerial phenomena. Marketing an innovation source of imagination is a quest pursued by many actors. Finance does not escape the influence of the imagination. A stock market share can gain value or lose massively if an imaginary, positive or negative is captured by actors with limited rationality. To invest in a company is to adhere to its vision of the future, to the interest of its products for Humanity. Speculative bubbles can appear when the vision of the leader charms a large number of investors.

The risk of bursting of the bubble appears when this vision appears remote from the reality, for example when the technology is not at the level of the expectation of investors, or when customers do not wish to acquire it. The different economic actors deploy behaviors with specific rationality. To consider them irrational would be wrong, rationality being dictated by imaginary considerations. When an actor invests in the computer or telecommunications sector, for example, he adheres to visions of the future in the more or less long term. In the short term, he will speculate on the success of a new product, on punctual financial indicators. In the medium or long term, his commitment will be different. It will adhere to a long-term vision of the sector, to sectoral myths that are often forged by fiction, in this case by science fiction. In the telecommunications sector, the myth of cyberspace and virtual immersion has become increasingly complex since the 1980s and the publication of William Gibson's book *Neuromancer*. In the space sector, there are many sectoral myths. Terraforming is one of the most important, with supra-luminous speed or the exploitation of asteroids. In the transport sector, flying cars, teleports or autonomous cars have long had an influence on engineers with the skills to patent and design these imaginary technologies. Markets are structured around sectoral myths, whose function is to federate investors and consumers. Science fiction has been presented as an essential element of innovative systems in recent years and should increase its influence during the fourth industrial revolution.

Actors adhere to a specific form of rationality when it comes to innovating. Science fiction rationality is the consequence of the postmodern paradigm and its consequence. It proposes to move to a new civilizational stage, erecting the imaginary as the guiding principle of techno-social mutations. Thinking the future is science fiction, which is itself reformatted to meet the demands of traditional economic rationality. Imaginary is not the substitute for scientific rationality either. The influence of science fiction is more and more obvious, because it allows us to think of a world that looks more and more like the futures described for decades, for better or for worse. However, companies and institutions are aware of the need to filter these fictions of their negative dimension to retain only certain elements, such as utopian technologies and related societal issues linked to their marketing. Science fiction rationality uses the imaginary to captivate markets and investors. It is only a tiny part of the rational processes in works in research and development. Since its inception, science fiction has steadily increased its influence to the point of constituting a crucial element in the construction of strategic and managerial discourses in the techno-scientific sectors. From then on, what role will science fiction have in decision-making processes during the new industrial revolution? Two main possibilities could be confronted. Either innovators will develop the science fictional rationality, more and more, until it becomes harmful to the instrumental rationality inherent in scientific capitalism (Weick, 1979, 1995). Either it will be criticized and annihilated by other ways of thinking, considered more relevant to build the world of tomorrow. In both cases, it will be taken into account in the construction of discourses and economic models.

The Place of Geek Culture in Innovative Systems

Geeks have long been regarded as fanatical individuals of science and technology, fans of science fiction and have contributed greatly to the development and dissemination of innovations all over the planet. Since the 1980s, they have gone from marginalized to leaders of global capitalism. Companies in Silicon Valley, including GAFA, were created by geeks. Their culture is assimilated to a positive way of thinking by more and more people, although some minds also criticize their imperialist and monopolistic tendencies potentially dangerous for the respect of individual freedoms. Geek culture is part of science-fiction rationality. Donna Harraway, in her *Cyborg Manifesto*, even believes that the new economic system replaces the bourgeois novel with science fiction. Science fiction has been an integral part of Anglo-Saxon soft power since the 1980s, and this trend may well increase in the coming decades. It is likely that the creation of science fiction is developing in most cultures in the future. Since the beginning of 2010, China has promoted the scientific imagination and the creation of science fiction narratives to develop the creativity and technical culture necessary for the country's productivity and cultural influence.

Geeks are also at the origin of an ideology more and more influential and could serve as a discursive matrix to the next industrial revolution: transhumanism. This movement is strongly influenced by science fiction. He advocates the pursuit of eternal life, total virtual immersion, among others, and considers that R & D will create a better world through science. Transhumanism is the subject of criticism, some even seeing the expression of a new totalitarianism that could lead to apocalyptic consequences and the disappearance of the human species and ecosystems.

Four levels of expression are distinguished at this stage of the analysis of the impact of science fiction on the economy of the next industrial revolution.

1) The imagination is formatted as imaginary by the cultural system, in this case by Hollywood.
2) Some works stand out and are branded as sectoral myths by innovators.

3) Science-fiction is exploited by an ideology, transhumanism, which seeks to realize the most imaginative fictions.
4) Science fictive rationality is a way of thinking based on the fusion of imagination and rationality. Science fiction will then have a double effect. It will help to humanize scientific thought and avoid the advent of an instrumental rationality that is all-powerful and uncontrollable, totalitarian. It will also help to spread the techno-scientific culture to an increasingly wide audience, with the aim of making it compatible with other ethical considerations such as sustainable development, corporate social responsibility and the preservation of nature.

Industrial Revolution and Technical Imagination

An industrial revolution agitates the collective imagination of the societies in which they occur (Dosi, 1988). An imaginary reflects the ancestral social structures, in the form of myths. It can also transcend the present and the real to help individuals plan for the future. To prophesy, however, has not always been a practice tolerated and appreciated by the ruling classes. During the Middle Ages, and part of the Renaissance, the prophets, oracles and soothsayers were often persecuted and assimilated to the representatives of Satan. Christianity regarded the imaginary of the future as a danger to its hegemony, the apocalyptic imaginary constituting a religious base collectively shared and sufficient to ensure the stability of the social order. The industrial revolution was accompanied by a political and cultural revolution in the West. Christianity was challenged, and gradually, from decades to decades, the Christian foundations of civilizations were relativised and marginalized. Positivism contributed to the spread of science, which denounced the manipulation of the people by religions whose principles did not stand up to scientific analysis. Yet the spirits of anti-religious enlightenment forgot the tendency of Humanity to base its organization on spiritualities and religions. The era of scientific fictions gradually took the place of mythologies and biblical stories. The influence of Christianity did not disappear, however, far from it (Paik, 2010). Science fiction is in fact a re-actualization of founding biblical themes. Most stories are inspired by the great mythologies and religions, of Western, and other civilizations. Georges Lucas, creator of the *Star Wars* series, was inspired by the work on the myths of Joseph Campbell to imagine a universe that touches the archetypes of the audience. Most myths are based on a common structure, and the human mind is sensitive to stories that refer to what Campbell calls monomyth.

The Industrial Revolution rewrites the great myths and religious narratives by integrating a futuristic and technological aesthetic into its representations. Science fiction was not built in rupture with the western history of the imaginary. It has prolonged it, and gradually develops a performative technological ideology. The

Great Industrial Revolution that began in the eighteenth century in Europe generates a protean technical imagination. Each industrial revolution exploits it, through art and science fiction, to colonize the spirits in futuristic representations. In innovative communities, science fiction plays the role of a proto-religious thought, which updates technological archetypes that we call technotypes. These are present in a primordial human psyche and gradually reveal themselves, following the processes of technological innovation. Technotypes must be studied by comparing the history of the technical imagination and the history of techniques. Science is gradually revealing new technological horizons, gradually revealing the archetypal structures of the human technical imagination. These technotypes constitute an unconscious technological project that Humanity is in charge of realizing. Industrial revolutions are based on systems of techno-futuristic representations that they take more and more seriously, curious to know the teleological meaning of their innovations.

REFERENCES

Aldridge, A. (1984). *The scientific world view in dystopia*. Ann Arbor, MI: UMI Research Press.

Alkon, P. K. (2002). *Science Fiction Before 1900: Imagination Discovers Technology*. Londres: Routledge.

Alkon, P. K. (2010). *Origins of Futuristic Fiction*. University of Georgia Press.

Aronowitz, S. (1995). *Technoscience and Cyberculture*. Londres: Routledge.

Barbrook, R. (2007). *Imaginary futures – From thinking machines to the global village*. Londres: Pluto Press.

Brake, M., & Hook, N. (2008). *Different engines – How science drives fiction and fiction drives science*. New York: Macmillan Science.

Buderi, R. (2000). *Engines of tomorrow: how the world's best companies are using their research labs to win the future*. New York: Simon & Schuster.

Bukatman, S. (1993). *Terminal Identity: The virtual subject in postmodern science fiction, Durham*. Londres: Duke University Press. doi:10.1215/9780822379287

Davis, E. (2015). *TechGnosis: Myth, Magic, and Mysticism in the Age of Information*. Berkeley: North Atlantic Books.

De Witt, D. K. (2003). *Astrofuturism: science, race and visions of utopia in space*. University of Pennsylvania Press.

Disch, T. (2000). *The dreams our stuff is made of: how science fiction conquered the world*. New York, Londres, Toronto: Free Press.

Dosi, G. (1982). Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinant and Direction of Technological Change. *Research Policy*, *11*(3), 147–162. doi:10.1016/0048-7333(82)90016-6

Dregni, E. (2006). Follies of science – 20th century visions of our fantastic future. Denver, CO: Speck Press.

Johnson, B. D. (2011). *Science fiction for prototyping: Designing the future with science fiction*. Morgan & Claypool Publishers.

Marcus, G. E. (1995). *Technoscientific Imaginaries*. Chicago: University of Chicago Press.

McCurdy, H. (1997). *Space and the American imagination*. Washington, DC: Smithsonian Institution Press.

Michaud, T. (2008). *Télécommunications et science-fiction*. Paris: Editions Memoriae.

Michaud, T. (2010). *La stratégie comme discours, la science-fiction dans les centres de recherche et développement*. Paris: L'Harmattan.

Michaud, T. (2017). *Innovation, between science and science fiction*. Wiley. doi:10.1002/9781119427568

Michaud, T. (2018). *La réalité virtuelle, de la science-fiction à l'innovation*. L'Harmattan.

Paik, P. Y. (2010). *From utopia to apocalypse: science fiction and the politics of catastrophe*. University of Minnesota Press. doi:10.5749/minnesota/9780816650781.001.0001

Parker, M. (Ed.). (1992). *Utopia and Organization*. Oxford, UK: Blackwell.

Scholes, R. E. (1994). Structural fabulation: an essay on fiction of the future. UMI.

Shedroff, N., & Noessel, C. (2012). *Make it so: Interaction design lessons from science fiction*. New York: Rosenfeld Media. doi:10.1145/2254556.2254561

Westfahl, G. (1998). The mechanics of wonder: the creation of the idea of science fiction. Liverpool University Press.

Weick, K. E. (1979). *The social psychology of organizing*. New York: McGraw-Hill.

Weick, K.E. (1995). *Sensemaking in organizations*. Sage Publications.

Chapter 3
From the Visual Turn to Turned Up Visuality:
Modes of Interaction in the Digitalized Era and Ways to Utilize Them

Julien Bucher
Chemnitz University of Technology, Germany

Anja Weller
Saxon State Ministry of Education and Cultural Affairs, Germany

ABSTRACT

The humanities and social sciences discovered the field of visual research in the 1990s and proclaimed several "turns" to emphasize the importance of visuality (or the visual mode) and shape the future direction of research: imagic turn, pictorial turn, iconic turn, and visualistic turn. Almost 30 years later, the individual lifeworlds are heavily influenced by the digitalization of technologies and the globalization of material and immaterial goods – products, ideas, and imaginations that rely on certain ways of visual presentation, images, and visual media in general. The individual lifeworlds are increasingly based on digitally mediated visuals and the interaction with as well as the communication using them (often intertwined with direct ways to interact, like touch, speech, or gestures). Visual-based alternatives to commonly used methods like interviews and surveys are discussed, finishing off with an introduction to the methodology of the creative interview, a qualitative instrument to gain and explicate information, and imaginations using respondent-produced sketches and drawings.

DOI: 10.4018/978-1-5225-9188-7.ch003

INTRODUCTION

The humanities and social sciences discovered the field of visual research in the 1990s and proclaimed several ‘turns’ to emphasize the importance of visuality (or the visual mode) and shape the future direction of research: e.g. imagic turn (Fellmann 1991), pictorial turn (Mitchell 1992), iconic turn (Boehm 1994) and visualistic turn (Sachs-Hombach 1993). Almost 30 years later, the individual lifeworlds are heavily influenced by the digitalization of technologies and the globalization of material and immaterial goods – products, ideas, and imaginations, that rely on certain ways of visual presentation, images and visual media in general. The first two decades of the 21st century are shaped by digital technologies and innovations that exploit these technologies and utilize them. This revolution in the making is characterized by new technologies that fuse the physical, digital and biological worlds (Schwab 2017, Schwab et al. 2018). This revolution is accompanied by the development and formation of global cultures that are fostered by digital technologies with a low threshold, like the immaterial information and imagination, communication and networking resources of the Internet and the World Wide Web. In these global cultures, visuals gained a new power because of their quasi-universal comprehensibility (in contrast to language-specific speech and text) and their easy and fast diffusion via networks, platforms, social communities, and the globalized professional media industry. New tools like tablets and applications like Instagram accelerate the impact of images and imaginations in the distribution and perception of information from individuals as well as organizations and political actors.

This emphasis on the visual mode of perception, representation, and communication in the 21st century has created the need to grasp, study and understand the usage of the visual mode as well as the desire to foster this mode for research and value creation. It spawned several trends spanning from the AI-based, automated analysis of images (think of e.g. face detection on surveillance cameras and automated digital image search and interpretation), heavily image- and visualization-based methods to foster creativity to the use of participant-produced photographs and images in social research. This chapter focuses on how these innovative approaches can be utilized to gain hidden knowledge, to gain new aspects, to solve problems or to foster creativity.

The chapter begins with an introduction to modern mass media and the construction of global identities. Then the increased and increasing importance of visuality is presented. Following, visual knowledge, as well as perception and processing of visual information in psychology and cognition research, is shown. Thereafter visuality in the social sciences and visual (research) methods are presented to shed light on the use of images in the research process. The chapter finishes with the introduction of the creative interview, presented and illustrated with several case examples, a summary, and outlook.

MEDIA AND THE CONSTRUCTION OF GLOBAL IDENTITIES

The era, we live in, is shaped by processes of globalization fostered by the modern mass media and the increasingly ubiquitous interconnectedness. Foreign cultures and concepts of life characterized by particular circumstances like war, luxury, and natural disasters are increasingly facilitated and communicated by and via modern media that extensively use the visual mode. Beck (1999, p. 29) identified the streams of images of the global culture industries as one of the eight reasons for the irreversibility of globality. Such media images influence and construct variations of social life and action that can be compared and used for individual and social distinction as well as identification. It is an integral element of this era that more people than ever before have access to a bigger set of (representations of) concepts of life than ever before (Appadurai 2010, p. 53). Appadurai (2010, p. 53) is not only emphasizing that imaginations have gained importance for and in the social world but also that mass media are the main source for these imaginations, that steadily communicate and produce these contrasting concepts of life and quite substantially influence concepts of life and action. Describing how the influence of imaginations distributed by mass media has risen and gained relevance for individuals as well as groups, he argues that this new role and enhanced importance of imaginations is an indicator of the postelectronic world. These imaginations are highly visually underpinned narratives and metaphors that are used to create imaginative lifeworlds and constitute the foundation for the creation of images of the other. These images of the other become relevant as soon as thoughts about the own belongingness and mobility arise and decisions regarding the own living and working location are made (Appadurai 2010, 1996, pp. 35-36.).

Within the globalized modern world-system, such artificially-created and media-influenced narratives and images are integrated into the ways of life of citizens (of states) and contrast historically established influences like language, territory, and kinship, that characterize the national state (Appadurai 2010, 1996, p. 161). Appadurai's work is influenced by Benedict Anderson (2016, 1983), who coined the understanding of the national state as an imagined community. A community, in which the majority of members do not meet or even know each other, a (comm-) unity based on imagination.

Nations are imaginations per se, they are limited, sovereign and socially imagined (Anderson 2016, 1983, pp. 6-7.). Such imaginations of nations influence and inform their inhabitants through media. Anderson focused on the print media and the print industry, the "print-capitalism" (Anderson 2016, 1983). Global media happenings like movies or sports events are the extension and source of such imaginations that bear societies with (to a certain extent) homogenous mentalities and emotions (Appadurai 2010, 1996, p. 8).

The interpretation of local everyday life and its inherent conflicts is affected by interpretations stemming from a broad global context that gain local significance, offered and diffused by and via media. This way emotions and attitudes on the local level are affected by global influences. In particular images of the other, the alien are generated and integrated into the construction of the lifeworld.

The global creation of the imagined other by the media is often embedded in an argumentation of origin and these globally generated identities are marked as natural ones. Appadurai (2010, 1996, pp. 155-156.) highlighted a problematic aspect: „Such representations of identity (and identification) seem even more plausible in a world of migrants and mass media, which can subvert the everyday certainties that come from face-to-face knowledge of the ethnic Other." From the perspective of the nation-state the description (proposal and institution) of a national culture or identity, and the homogenization of its citizens is the aim of the imaginative construction of identity. Looking at the proliferation of mass media and the migration of humans, the reconstruction of identities seems a necessity (Appadurai 2010, 1996, p. 156). The technology to communicate, consume and interact via such media is based on the digitalization and the beforementioned interconnectedness of the devices used. Social Media supports and expands the possibilities of persons to shape, present and share an image of themselves and to get feedback. The graphic-user-interfaces are increasingly important to perceive the visual-based mass media, which also shows e.g. in the development of smartphones from having small screens and keyboards to huge touchscreens without dedicated hardware keyboards. In consequence, perception and interaction are characterized by this new visuality. In addition, the interaction with these devices is multimodal and enables intuitive usage, combining the graphic with touch and speech-based user interfaces.

VISUALITY AND KNOWLEDGE

The point of departure is the basic assumption of the visual turn, that cognition is not solely evoked by speech but also by images, following the argumentation of the iconic turn proposed by Boehm (2007). Pink (2012, p. 7) argued, that the use of visual methods (or techniques) is generating new types of knowledge. Wopfner (2012) stated, that there are types of knowledge, that aren't part of the conscious plane for the most part, since they are located on a pre-reflexive plane as rather visually than verbally coded information. Foucault (1980) coined the term 'subjugated knowledge'. Although knowledge can be generated in different ways, it is often limited or reduced to the kind of knowledge that is available in printed speech. Visual knowledge is often hidden and suppressed. Edgar (2004, p. 90) points out, that visual methods particularly provide access to implicit notions of the world and an intuitive way to the self and the identity of the probands.

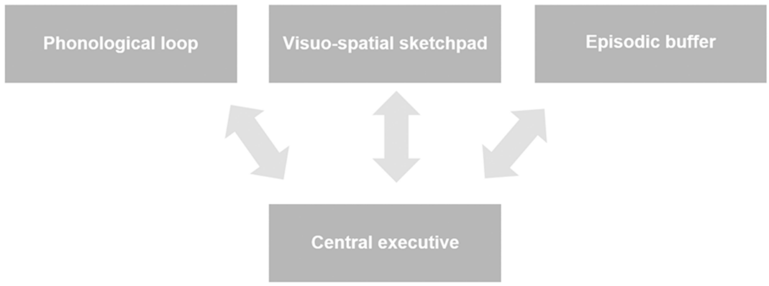
Pictures not only express knowledge and insight in a different way than language does, but they also have another quality. Petersen and Schwender (2011) declared that pictures have their own logic, by showing depictions of imaginations in detail. In doing so, they are always concrete and not only abstractions. Whereas texts do generalize, showing contrasts and analogies or making statements, expressing hypothesis and assumptions. In contrast to pictures, texts underperform when it comes to expressing circumstances in detail (Petersen & Schwender, 2011, p. 21).

Another distinction in the results is grounded in the respective characteristics (Gauntlett, 2007). The linearity of texts on the one hand and the simultaneousness of images on the other hand. The interpretation and presentation of knowledge are affected in the way, that images allow to see information without "an order or a hierarchy" (Gauntlett, 2007, p. 183). Gauntlett (2007, p. 183) highlights the following difference: "Language may be needed to *explain* the visuals, but the image remains primary and shows the relationships between parts most effectively." Especially when it comes to difficult and complex topics visual methods help to explore and express them. They also allow access to individual feelings and an insider's view (Gauntlett, 2007, p. 30).

Through the different ways of processing visual and verbal information in the brain, it is assumed that in these processes different cognitions are created. Through the use and utilization of images, it is possible to tap into new relations of sense and meaning in comparison to conventional language-based methods. There is also the argument that visual experiences can only be accessed and investigated via the inclusion of images. The theoretical background for this assumption is provided by the dual-coding theory by Paivio (1986). Banks (2007, p. 119) has additional arguments for the inequality of the results: „Visual methodologies relentlessly particularize, highlight the unique, go beyond the standardization of statistics and language". The articulation via pictures initiates a creative process, which prompts another mode of reflection than language does. Moreover, the researcher fades into the background, the facilitation of creativity and the visual mode determine the action and to lesser extent parameters like the language, mood and behavior of the researcher. Banks (2007, pp. 182-183) describes it as follows:

Many people are inexperienced in transferring their thoughts about personal or social matters into the kind of talk that you would share with a researcher. It can also be difficult to talk instantly about abstract concepts such as identity or emotion. If participants are invited to spend time in the reflective process of making something, however, they have the opportunity to consider what is particularly important to them before they are asked to generate speech.

Figure 1. Baddeley's model of working memory (Baddeley 1986, 1992, 2000)



PROCESSING AND PERCEIVING VISUAL INFORMATION

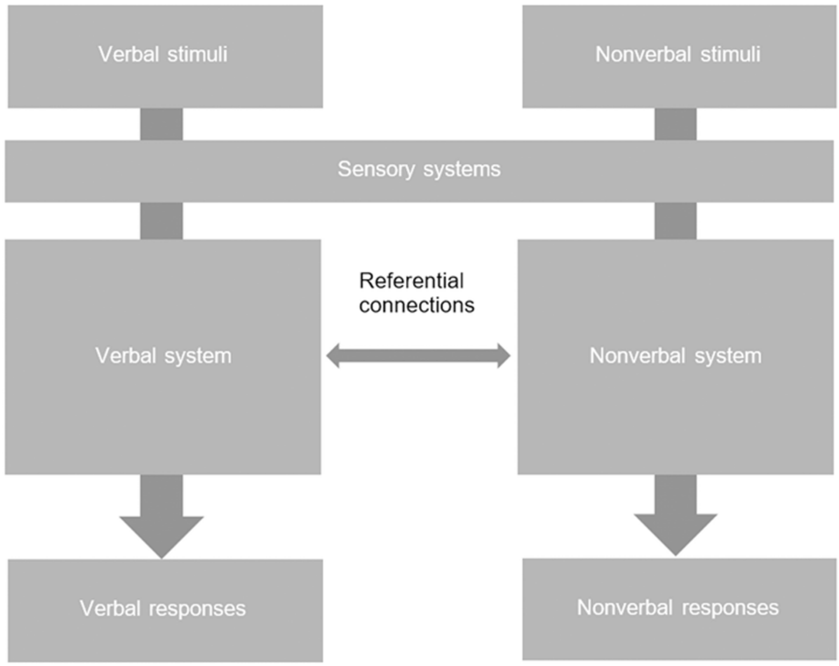
The foundation for the modern understanding of the human processing of visual information was set by Alan Baddeley (1986, 1992, 2000) with the conception of the popular model of the working memory and several hypotheses based on it. One of them is the hypothesis that there is a memory for visual and auditive information. Baddeley argued that these memories are independent of each other and that the auditive and visual as well as scenic information are processed within this separate memories.

Auditive information is stored in the phonological loop while the visuospatial sketchpad is processing visual (as well as spatial and haptic) information. The central executive is distributing these different resources and is placed on a higher level.

Pavio (1971, 1978) not only emphasized the separate memory for visual information in his dual coding theory, but he also added systems that process verbal and nonverbal information. Images are processed and coded in both, the verbal as well as the imaginative system. An illustrative example of this concept is the image of a tree that evokes the figurative image of a tree as well as the term *tree*. The information is dually encoded. In the processing of speech dual coding is not always the case. Abstract terms and concepts that are not coded with a specific object of reference or symbol don't evoke such mental images. The model of dual coding describes processes that take place during action and thought, emphasizing the importance and role of verbal and visual contents of consciousness.

Castoriadis (1990, 1984, p. 217) noted, that every symbol includes an imaginary component. These components are unconsciously available and automatically evoked when it comes to storing information, processing it or making sense of something. In his remarks on the construction of thought Schütz (1971) elaborates on imagination as the source for hypothetical sensual images essential for perception (Schütz, 1971, p. 4). Imaginations are a constituting element of the construction and disclosure (or interpretation) of the human world. This culminates his statement, that "strictly

Figure 2. Paivio's dual code theory illustrates how the two systems are bidirectional coupled. They use different forms of mental representation but they are connected (Paivio 1971, 1978)



speaking, there are no such things as facts, pure and simple" (Schütz, 1962, p. 5) since they are always already interpreted.

Rudolf Arnheim (1988, 1977) displays the importance of the image by describing perception as a process of thought and insight in his book on visual thinking. Starting off his investigations with thoughts on the negligence of the arts. He reasons that the arts are based on perception and that perception is in low regards since it doesn't require thought (Arnheim 1988, 1977, p. 15). He argues, that seeing is not limited to collecting facts about certain sensory qualities, objects or processes, but rather enables to understand general properties. Seeing is not only about theoretical, formal knowledge but also all the other kinds of knowledge that lay the foundation for every concept formation. During a process of perception, the human consciousness is not limited to the present immediate stimuli that it receives through the eyes, it functions with a rich memory inventory of imaginations and that constitutes a system of concepts of perspectives as the return of lifelong experience. Visual thinking is displayed in the imagination of the artist, the world of insight of the scholar and in general everywhere, where someone is messing with problems in his head (Arnheim 1988, 1977, p. 277).

In conclusion, the processing and storage of information are occurring in a verbal and visual (or non-verbal) system. Regardless of the kind of information, they can be encoded using visual imaginations. Such images play a role in the formation of interpretations and the subjective and social construction of the lifeworld. In creative activities, such visual imaginations are evoked and the produced visual artifact provides insights regarding the individual mental, imaginative and perceived images. It is not possible to separate these images precisely (e.g. between inner and outer images) since they are coupled within the construction of the lifeworld and only working together enable cognition.

VISUALITY IN SOCIAL RESEARCH

The most common approach in qualitative research with participants is the ethnographic instrument of the interview, where an individual (or a group) is requested to speak and reflect their experiences verbally. These interviews are more or less prestructured, get transcribed afterward before being analyzed. This way the speech is dominating the process, setting a temporal perspective that is organizing what is said. Visual methods, in contrast, can overcome these limitations and display the context of the experiences:

When using purely verbal methods, this has been observed to lead to such narratives being overwhelmingly organized in terms of time. Studies incorporating visual methods have on the other hand been shown to succeed in disrupting such narratives and encourage participants to also reflect on the social and material contexts of their experiences. Not just when but where experiences emerge. (Reavey, 2011, p. 8)

The inclusion of images in research offers access to originary information and an alternative approach to obtaining empirical data. However, images still take a back seat in empirical qualitative research. Jon Prosser (2006) argues, that the marginalization of image-based research stems from the practice of and focus on speech and text in the last 100 years of social research. He claims that the research community undervalues image-based research despite its potential contribution. Spencer (2011) claims that it is hardly surprising that images are rarely used since they are hardly reliable and difficult to categorize. Hence they have been used supplementary to speech and traditional research methods, if they were used after all (Spencer, 2011, p. 2). The use of (and not only analysis of existing) images has so far mostly been limited to line drawings and black-and-white photography, with the photographs mainly used to illustrate the (group of) researcher(s) and the research object (Prosser, 2006, p, 98). One of the main arguments for the use of images is the fact and circumstance, that they are polysemous and don't communicate cognition. Information about the context and previous reflections are inherent to perception and determine the process of an image interpretation, creating complex methodological and contentual problems. As a consequence, the acceptance of the use of images is quite low beyond documentation and illustration of the verbal data. Images aren't recognized as storages for bodies of knowledge since they sophisticate (or distort) the object of research. It is also claimed, that image-based approaches only produce biased results, as the image production is always bound to a specific social context. Therefore the engagement in and analysis of images is unnecessary. Prosser states, that there are only a few attempts being made to find solutions for the described problems or look for analogous problems regarding speech. In addition, specific subdisciplines like visual anthropology and visual sociology have a low acceptance within their main disciplines, stemming from the epistemic roots of anthropology and sociology:

1. the continuing influence of quantitative epistemology and an empiricist view of science on qualitative research; and perhaps consequentially
2. the qualitative paradigm uses words or occasionally numbers and only very rarely images except as a representation of words and numbers (Prosser, 2006, n. pag.).

To conclude - the marginal acceptance of image-based research within the main disciplines of the social sciences traces back to the circumstance, that this approach is quite new and entered a rather competitive field (empirical social science research), that in addition is divided into two ideologies. Image-based research is on the one hand disregarded by the quantitive epistemology as being qualitative and thus not valid and reliable; and on the other hand disregarded within the qualitative epistemology for being not speech- and text-centric, ambiguous and imprecise, disregarding that the same has been said about speech- and text-based qualitative research (not to mention observational approaches).

Stephen Spencer (2011) brought forward two arguments for the inherence of the visual, the relevance of visuals in social research, and the importance of images in our societies, pointing towards the potential of visual methods:

Firstly, that the visual is recognized as central to the human condition and to expressions of humanity which pre-date language, affecting our emotions, identities, memories and aspirations in a most profound way. We are visual beings in a world which is a visual array of meaning. Secondly, despite this, social sciences have undervalued the visual, or relegated its use to mere subsidiary illustrations to written text. However, in the last two decades, the interest in the visual dimension of social *life has rapidly increased; the potential of visual methods to provide a deeper and more subtle exploration of social contexts and relationships is recognized, allowing us to see the everyday with new eyes. (Spencer, 2011, p. 1)*

He argues that the use of images has three advantages and emphasizes the functions and the outcome that images generate in contrast to speech:

First, the visual has an explicitness and immediacy which delivers a multisensory impact. […] It is an immediate and authentic form which verbal accounts are unable to fully encompass. […] Second, […], visual records can create vivid and authentic personal narratives. […] Third, […], visual material provides a form of 'thick description' which helps in the exploration and understanding of theoretical ideas. (Spencer, 2011, p. 32)

Pictures are often used in Social Health Care initiatives with kids and teenagers since they offer the possibility to be utilized continuously in the pedagogic process. They can be used by teachers later on as comparison or illustration. They can also be used as a stimulus to initiate speech and interaction in follow up tasks. Additionally, such use of pictures is quite easy and cheap to do. Another possible use case is the exhibition in public spaces to include the general public and transport the imaginative worlds from the scholarly to the public space.

[…] people take the ideas and concepts of sociology and draw them back into the public sphere where they may become popular currency in the description of social phenomena; rather undermining the sociological project of creating a critical distance from the commonsense of social life. (Spencer, 2011, p. 37)

Pink (2012, p. 7) describes the idea behind visual methods as „routes to knowledge", implicating that there are different types of knowledge and approaches as well as different manners depending on the investigated group of individuals. Spencer (2011, p. 1) also mentions that knowledge, that so far has been text- and speech-based, now is transforming, including visual information and attributes this development to the development of technology, media, and the society. But the exact definition of visual methods turned out to be a challenge:

The question of defining visual methodology as a field of practice is further complicated by the fact that within its discipline and also task-specific uses and understandings of the visual exist alongside and in relation to visual work that is self-consciously interdisciplinary. (Pink, 2012, p. 8)

At the beginning of the 21st century, several publications were released that introduce single visual methods and methodologies as well as anthologies that integrate various visual methods. Several disciplines emerged that use the term *visual* and that focus on any kind of artifacts represented by media: Visual communication, visual sociology, visual anthropology, visual ethnography, etc. These artifacts are studied for purposes and goals depending on the specific discipline by using different kinds of pictures (f. e. photos, articles or advertisments). The majority of the publications in German can be assigned to the field of visual communication, while in english publications the visual anthropology and visual ethnography seem to gain traction.

In 1996 the „Handbook of Visual Analysis" by Van Leeuwen and Jewitt was published, that can also be assigned to the field of visual communication. The authors base the development of their visual analysis on semiotics and work with the premise that images are ambiguous to the extent that their meaning and impact can only be reconstructed if they are adapted to speech (Kress & Van Leeuwen, 1996, p. 16). Images are treated equivalent to speech and the semiotic aspects as well as the grammar of speech is carried over. The methodology is used for a wide range of artifacts, from children drawings to three-dimensional objects. Children drawings are also the research object of two articles in the handbook published by Prosser (1998), Wakefield and Underwager (1998) show how these images can be utilized in the context of sexual abuse and introduce image-based methods in psychology. Wetton and McWhirter (1998) use children's drawings for health education in combination with interviews utilizing them as a starting point, a stimulus and foundation for the conversation.

IMAGES IN THE PROCESS OF RESEARCH

Stages Of Images

Images can be used in research to fulfill different functionalities and to produce different outcomes. To understand the possibilities of the use of images in research the three stages of images formulated by Huss (2012) are introduced. The first stage focuses on the research process, often as an additional tool. Images are utilized to trigger and facilitate conversations, to document the research process, creating additional data in the form of e.g. sketches and photographs. This way images are mainly used in social work (Huss, 2012, p. 1442).

The second stage is the use of images as original data without additional interpretation by the corresponding participant or limited to being a vehicle to foster the research process. Typically the composition, including color, form, shape, and composition of the image and its content is analyzed, including looking at the semantics and the emotional significance. The analysis is often based on this distinction and the comparission of the two layers. This happens parallel to the text analysis that is also looking at the form and the content (Huss, 2012, p. 1443). This approach is prominently used in the research on visual culture and art history. In psychology, analyzing the composition of images is part of the evaluation (or interpretation) of psychological sign tests, designed to measure certain functionalities.

The last stage is the interpretation of the process and/or the product, integrating verbal data about the images, elaborations, repetitions, representations, and re-interpretations (Huss, 2012, p. 1443). This approach is used in art therapy. In art-based research, the image is the point of departure to enable new narrative approaches. Within social research, it is argued that images contain universal components besides the subjective experience, reasoned with the argument that images are always created in a specific social and cultural context and that this specific context is a characteristic of an image (Huss, 2012, p. 1443).

The Utilization Of Images

Images can be utilized in a research project during the different stages of the research process, with different functions depending on the stage and way of application. Huss (2012) proposed a typology based on the use of images in the process to demystify the use of images and show, how images can be utilized. He proposed four different functionalities:

1. Images as additional data
2. Images as method
3. Images as subject or object
4. Images as product of the research.

Images can be utilized in the research process as additional data, enriching e.g. verbal and textual data. Often these images are found during the research process and discarded, because they are not designated as considered data in the research design. In case such visual data is actually considered and used, it offers the researcher the opportunity to analyze add a new perspective on the research object, enabling the identification of alternative or even opposing interpretations compared to verbal data (Huss, 2012, p. 1448). This way perspectives of different codality on a certain researched phenomenon can be collected and integrated, enriching the understanding of the research object, accordingly it is recommended to integrate verbal and visual data if the research aims at the deep and comprehensive understanding of a topic or phenomenon (Huss, 2012, p. 1449).

Using images as a method indicates, the focus of the investigation lies on the actual process in which participants generate images. This way participants that have problems with the verbalization due to e.g. cultural or personal reservations regarding the subject of the investigation can be stimulated to express themselves visually. This approach is used in social work, e.g. in projects that aim to empower minorities. It is a central method in art-based research and art therapy (Huss, 2012, p. 1450). In case images are utilized as the subject or object of research they can be analyzed using different theories (Huss, 2012, p. 1451). This way the ambiguity of the image is used and integrated into the analysis. Images are also utilized as the product of a research process. This functionality of an image is characterized by the display of the images in a public space so that the public can participate in the production, dissemination of the image, e.g. in the form of an exhibition. The produced pictures are self-explanatory as visual results. In social work this approach is used to give oppressed social groups a voice: „Images, therefore, become a vehicle for social change, both by process (thereby empowering disenfranchised groups) and by producing products (thereby influencing power holders).“ (Huss, 2012, p. 1452)

Forms Of Visual Data

Besides the aforementioned stages and functions of images it is relevant to consider the form respectively the origin of the images and their creators. Research approaches that utilize images differ not only regarding their respective discipline or the specific kind of used images, but also regarding the origin and creators of images. Prosser (1998) described the so called „4 Rs of visual research methods“ to distinguish between images:

- **R**esearcher-found visual data
- **R**esearcher-created visual data
- **R**espondent-generated visual data
- **R**epresentation and visual research

Researcher-found visual data encompasses e.g. street art, cartoons, newspaper photographs and images from the web. In case the researcher creates visual data herself or himself, it is often to document, visually structure, present or represent impressions, insights, interpretations or visual information. Visual data generated by respondents refers to original visual artifacts like sketches and drawings, photographs or videos created by participants of the respective research initiative. The fourth *R* is about the way the research is represented. To show the research results it is e.g. possible to present them in a diagram, graph or another visual form to point out what the researcher wants to express.

INTRODUCTION TO THE METHODOLOGY OF THE CREATIVE INTERVIEW

In the everyday lifeworld, relevance structures contribute to the intersubjective communication. For the construction of the lifeworld, humans use a diverse set of forms of knowledge like bodily experience, imaginations, and visual knowledge, that enable them to communicate and interact. With the creative interview (Weller 2018, Weller & Bucher 2016) a creative examination is evoked in order to make these hidden bodies of knowledge visible, experienceable and investigatable. Imaginations are integrated into a global network of knowledge (Appadurai, 2010, 1996) and refer to the prominence of images in reality as well as to the lifeworld itself. The everyday lifeworld refers to orders of the visible (Waldenfels, 1999) and is inseparably connected to the bodies of knowledge as well as to the social imaginary.

The methodology of the creative interview aims to uncover and render these orders and imaginations visible using respondent-generated pictures. The creator is challenged to interpret a stimulus (most likely a more or less specific topic, formulated as a question or a request) given by the researcher. The interpretation is articulated in the individual, contemplative creation of a visual artifact and (re-) shaped during the process.

Heinrich Wölfflin (1948 [1915]) contrasts the visual impression in order to discover the quality of expression. Goffman emphasizes that a certain set of pictures allows the recipient to see not only patterns but also different settings in just one frame (Goffman 1981: 109). Thus the pictures were analyzed as a corpus to broaden the horizon of interpretation. Analyzing multiple pictures and operating with a whole collection of pictures, recombining and regrouping them on picture tableaus was the primary mode of analysis. Through contrasting the pictures on tableaus, similarities and differences in the particular depictions became visible. Different frames of the picture tableaus allow the viewer to see one picture in the context of other pictures, directly contrast it another one and under a variety of themes. These themes allow focussing on the whole variety of the depiction. The use of picture tableaus (Warburg 2000) generates insights by giving rise to a multitude of perspectives on the images and provides an easy and expedient way to document the process of analysis. The picture tableaus especially support the visual mode of the analysis because they allow to focus on and see contrasts, enabling to envision the *tertium comparationis*. With the tableaus, the researcher is able to visualize themes and compositions without deconstructing the picture in single visual fragments. They allow concentrating on the pictures as holistic artifacts without ignoring single details, that show themselves in the simultaneous analysis of pictures. The tableaus furthermore allow the researcher to present results in intuitive, easy to understand and vivid way.

Figure 3. Male, 28 years old, self-portrait and portrait of his German friend

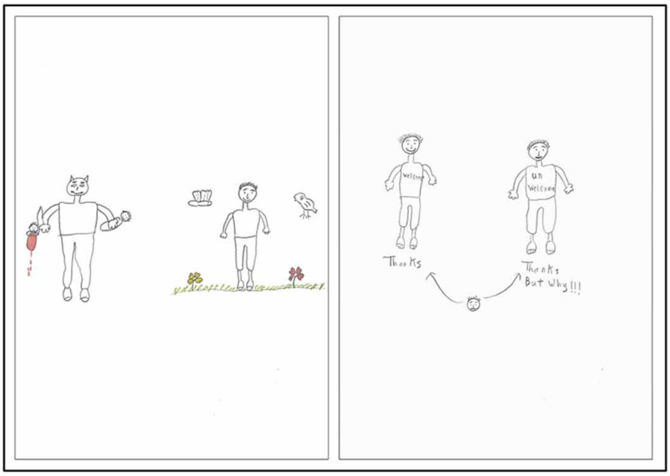
Four cases are concisely introduced in the following to illustrate the creative interview – how it may be used or integrated, and for which cases of application, research questions and groups of participants it is suitable. All of these research projects took place in the German city of Chemnitz with a broad spectrum of participants: Senior adults socialized in the former GDR; adult refugees from Morocco, the Kosovo and Syria; and pupils at the age of 11 to 19 years of a German Gymnasium (a kind of secondary school).

In the first investigation German people over the age of 40 were asked to take a comparison between the life in the GDR and the life today, requesting them to emphasize changes and similarities in their everyday and work life. For each point of time, the participants were asked to produce a sketch. The former GDR citizens visualized their imagination of living nowadays and back in the GDR. After the production of pictures, the adults were also asked to talk about the sketches. Through the visualization, the participants described their imagination and gave some context to the drawn situation in their lifes.

In another project, we worked with refugees of different nationalities that just landed in German reception camps 2 months prior. They were asked individually to create two pictures, one that depicts themselves in their current situation and one that depicts their image of a German person.

The actual creation of the image took place in a quiet setting, the participants created their images on their own and without a given timeframe or deadline. Various tools for the creation of the images were provided, like pencils, and pens and crayons in various colors. The participating refugees had fled from their homelands just recently and were hosted in Chemnitz at and for the time being. Following the creation of the visual artifacts, the interviews with the refugees were conducted

Figure 4. Male, 26 years old, from Damascus, Syria - Visualization of the situation in Syria and the current situation in Germany



using the respective pictures they created as a stimulus for the narration. During the process of the project some phenomena emerged, that are interesting for the research practice of the creative interview: All the participants, all male under 30 years old, adopted the role of a creator and each one produced (the requested) two pictures, they immersed in the contemplative, creative, interpretative visual work and were in a positive mood afterwards, what often contradicted their created visual artefacts and the stories and emotions they had to deal with.

In addition, narrating and explaining their pictures wasn't an easy task for a lot of them and in one case the participant was unable to verbalize the picture at all. This shows and exemplifies the relevance of an alternate approach to empirical interviewing that utilizes implicit (Polanyi, 1985) and visual (Arnheim, 1988, 1977) knowledge as well as social imagination to visualize the construction of the lifeworld.

In a third project, the creative interview was used in a school context. In nine different classes of a German school, over 100 pupils of different ages were asked to draw two pictures. The project was realized in the art lessons and the pupils had two and a half months to create the pictures. They were supposed to draw the connection between themselves and their hometown in the first picture and in the second picture to draw the connection between themselves and Europe.

The purpose was to figure out how the homeland in contrast to the continent is imagined and how they see themselves in relation to these two locations. In this case, the pupils also described their pictures subsequent to the production process. The pictures then were analyzed via a corpus-based analysis, inductively creating categories via contrasting and comparing different themes, compositions and forms

Figure 5. Critical Visualizations of the theme "I and Europe", created by two different pupils. On the left, there is no depiction of the creator in contrast to the depiction of the creator in the right image.

(Weller, 2018). In this project the images were utilized for several exhibitions (one took place at the city hall) taking the visualized imaginations and thoughts from the scholarly archive to a public space, to be perceived and interpreted by the general public. The interviews were used here as well. In the exhibition catalog the images and quotations from the corresponding interview were put next to each other. Applying the approach of gathering respondent-produced images regarding certain themes, questions and individual interpretations to explore their opinions, circumstances, and the individual as well as socio-cultural aspects of their lifeworlds a few lessons were learned. It often takes some individual encouragement to get the participants to start drawing/sketching, but once the tip of the pen hit the paper and the first line is drawn they usually kept going. Observing their work the authors noticed, that once this barrier was broken most of the participants entered a mode of concentrated, introspective creative activity. In general young individuals show less resistance than adult ones, but there is a lot of variation. Compared and especially in the combination with classic speech-based interviews the experience was made that in general, the participants showed less or no reservation expressing unpleasant and personal content and opinions, while in interviews the participants are often hardly capable of verbalizing this kind of content. The quite internal dialogue with the piece of paper seems to be way easier to handle than the dialogue with an (usually unfamiliar) interviewer vis-à-vis. Depending on the given question, theme or request and the magnitude of its implications the produced images are more or less hard to interpret and compare. If a wide spectrum is to be explored it is recommended to increase the number of participants and consider the range of participants that should participate, e.g. regarding their age, social status, gender, and cultural background. It may also help to illuminate the findings and sharpen the interpretation of the corpus of images to conduct interviews with the participants, letting them interpret and explicate their creations – but in our experience, such interviews rarely provided new information, it was mainly a helpful addition for the interpretation of the images. If introverted or uncommunicative (e.g. because of a personal crisis) individuals are to be interviewed, successfully requesting them to create an image in prior creates the possibility to use the image as an entry point for the dialogue.

SUMMARY AND OUTLOOK

The 4th industrial revolution is highly connected with the relevance of visuality in the digitalized society. The media produces an ongoing float of images, which are spread worldwide via the internet, the World Wide Web and other technologies. People are using the images, becoming a part of everyday lifeworlds as imaginations which refer no longer to local ideas but to a mixture of global imaginations created by the culture industry, by more or less prominent individuals on social media and the swarm of human and artificial users (bots) that create trends and emphasis. In this era, with its lifeworlds shaped by connected, global and highly visualized media content, life designs and imaginations, visuality is a dominant mode in the global system of communication and information. The authors argue that it is necessary to use the different modes of communication to explore the individual lifeworlds, the social structures embedded in these lifeworlds, the meanings, interpretations, and opinions utilizing the modes of communication that are to such an extend pronounced in the socialization nowadays. Methods and tools that utilize the visual and haptic mode are commonly used to foster creativity (and this also includes and applies to design thinking), e.g. visualization via mind maps and meta plans or the creation of 2D and 3D models. These methods often incorporate manual work in various ways, like cutting and folding paper, sketching and working with materials that have different haptic properties (e.g. texture, shape, and weight). Social research with participants, on the contrary, is still dominated by the verbal mode, especially common are the speech-based interviews in qualitative research and the text-based surveys in quantitative research. To offer an alternative the creative interview was introduced, an approach that creates an introspective situation were the participant is creating a sketch or an image manually in an introspective quiet dialogue with himself regarding a theme, request or question given by the respective researcher. This approach can be utilized with small to big numbers of participants and the images are analyzed as a corpus, via comparing and arranging the images in various ways to find spectra of aspects inductively or to verify or falsify aspects and theories deductively. Interviews can be used to sharpen the interpretation of a corpus or certain images, and vice versa can the quiet, introspective creation of an image be used as a starting point for an interview with an uncommunicative, e.g. introspective or traumatized individual. Looking forward this approach can also be used integrating digital media, using e.g. peripheral or standalone graphic tablets. This way it is easier to access, store and exchange the images among a potential research group, but so far the authors favor working analog with paper and different physical instruments to create an image because it seems more direct, intimate and accessible.

REFERENCES

Anderson, B. (2016). *Imagined Communities. Reflections on the Origin and Spread of Nationalism*. London, UK: Verso. (Original work published 1983)

Appadurai, A. (2010). *Modernity at Large. Cultural Dimensions of Globalization* (9th ed.). Minneapolis, MN: University of Minnesota Press. (Original work published 1996)

Arnheim, R. (1988). *Anschauliches Denken. Zur Einheit von Bild und Begriff* (6th ed.; G. Köln, Ed.). DuMont. (Original work published 1977)

Baddeley, A. D. (1986). *Working Memory*. New York, NY: Oxford University Press.

Baddeley, A. D. (1992). Working Memory. *Science. New Series*, *255*(5044), 556–559. PMID:1736359

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, *4*(11), 417–423. doi:10.1016/S1364-6613(00)01538-2 PMID:11058819

Banks, M. (2007). *Using Visual Data in Qualitative Research*. London, UK: Sage. doi:10.4135/9780857020260

Beck, U. (1999). *Was ist Globalisierung?* (6th ed.). Frankfurt am Main, Germany: Suhrkamp.

Boehm, G. (1994). *Was ist ein Bild?* (4th ed.). München, Germany: Fink.

Boehm, G. (2007). *Wie Bilder Sinn erzeugen. Die Macht des Zeigens*. Berlin, Germany: University Press.

Castoriadis, C. (1990). *Gesellschaft als imaginäre Institution. Entwurf einer politischen Philosophie*. Frankfurt am Main, Germany: Suhrkamp. (Original work published 1984)

Edgar, I. R. (2004). Imagework in ethnographic research. In Working Images. Visual Research and Representation in Ethnography (pp. 90-106). London, UK: Routledge.

Fellmann, F. (1991). *Symbolischer Pragmatismus. Hermeneutik nach Dilthey*. Hamburg, Germany: Rowohlt.

Foucault, M. (1980). *Power/Knowledge*. Harlow, UK: Prentice Hall.

Gauntlett, D. (2007). *Creative Explorations. New approaches to identities and audiences*. London, UK: Routledge. doi:10.4324/9780203961407

Huss, E. (2012). What we see and what we say: Combining visual an verbal information within socialwork research. *British Journal of Social Work*, *42*(8), 1440–1459. doi:10.1093/bjsw/bcr155

Kress, G., & Van Leeuwen, T. (1996). *Reading Images: The Grammar of Visual Design*. London, UK: Routledge.

Mitchell, W. J. T. (1992). The Pictorial Turn. In Artforum. Hamburg, Germany: Rowohlt.

Paivio, A. (1971). *Imagery and verbal processes*. New York, NY: Holt, Rinehart & Winston.

Paivio, A. (1978). A dual coding approach to perception and cognition. In H. L. Pick & E. Saltzmann (Eds.), *Modes of perceiving and processing information* (pp. 39–52). Hillsdale, NJ: Erlbaum.

Paivio, A. (1986). *Mental representations: a dual coding approach*. Oxford, UK: Oxford University.

Petersen, T., & Schwender, C. (2011). *Die Entschlüsselung der Bilder. Methoden zur Erforschungvisueller Kommunikation. Ein Handbuch*. Köln, Germany: Herbert von Halem.

Pink, S. (2012). Advances in Visual Methodology: An Introduction. In S. Pink (Ed.), *Advances inVisual Methodology* (pp. 3–16). London, UK: Sage. doi:10.4135/9781446250921.n1

Polanyi, M. (1985). *Implizites Wissen*. Frankfurt, Germany: Suhrkamp.

Prosser, J. (1998). *Image-based Research. A Sourcebook for Qualitative Researchers*. London, UK: Routledge.

Prosser, J. (2006). What Constitutes an Image-based Methodology? In P. Hamilton (Ed.), *VisualResearch Methods*. London, UK: Sage.

Reavey, P. (Ed.). (2011). Visual methods in psychology. Using and interpreting images in qualitativeresearch. Hove, UK: Psychology Press; Routledge.

Sachs-Hombach, K. (1993). *Das Bild als kommunikatives Medium. Elemente einer allgemeinen Bildwissenschaft*. Köln, Germany: Herbert von Halem.

Schütz, A. (1962). *Collected papers I: The problem of Social reality, part I*. Amsterdam, Netherlands: Martinus-Nijhoff.

Schütz, A. (1971). *Gesammelte Aufsätze: I Das Problem der sozialen Wirklichkeit*. Den Haag, Netherlands: Martinus Nijhoff.

Schwab, K. (2017). *The fourth industrial revolution*. London, UK: Portfolio Penguin.

Schwab, K., Davis, N., & Nadella, S. (2018). *Shaping the Future of the Fourth Industrial Revolution*. New York, NY: Currency.

Spencer, S. (2011). *Visual research methods in the social sciences. Awakening visions*. London, England: Routledge.

Wakefield, H., & Underwager, R. (1998). The Application of Images in Child Abuse Investigations. In J. Prosser (Ed.), *Image-based Research, A Sourcebook for Qualitative Researchers* (pp. 176–194). London, UK: Routledge.

Waldenfels, B. (1999). *Sinnesschwellen. Studien zur Phänomenologie des Fremden 3*. Frankfurt am Main, Germany: Suhrkamp.

Weller, A. (2018). *Das bildnerische Interview. Zur visualisierten Ordnung der Lebenswelt*. Chemnitz, Germany: TU Chemnitz.

Weller, A., & Bucher, J. (2016). Visualisierte Imaginationen der Lebenswelt und der Einfluss der Medien. In J. Raab & R. Keller (Eds.), *Wissensforschung – Forschungswissen. Beiträge und Debatten zum 1. Sektionskongress der Wissenssoziologie* (pp. 595–607). Weinheim, Germany: Beltz Juventa.

Wetton, N. M., & McWhirter, J. (1998). Images and Curriculum Development in Health Education. In J. Prosser (Ed.), *Image-based Research, A Sourcebook for Qualitative Researchers* (pp. 263–283). London, UK: Routledge.

Wölfflin, H. (1948). *Kunstgeschichtliche Grundbegriffe. Das Problem der Stilentwicklung in der neueren Kunst* (9th ed.). München, Germany: Münchner Verlag.

Wopfner, G. (2012). Zwischen Kindheit und Jugend – ein sehender Blick auf Kinderzeichnungen. *Journal für Psychologie*, *20*(3), 1–28.

Section 2

Creativity in the Fourth Industrial Revolution

Chapter 4
Is an Artist a Better Scientist?
An Empirical Analysis on the Impact That Artistic Activity Has on a Scientist's Achievement

Rebecca Frenz
Chemnitz University of Technology, Germany

Julien Bucher
Chemnitz University of Technology, Germany

Anja Hermann-Fankhänel
Chemnitz University of Technology, Germany

ABSTRACT

This chapter regards itself with the verification of theses by American scientist Robert Root-Bernstein who through scientific work spanning decades was able to find support for the argument that a successful scientist is more likely to have an artistic avocation than their less successful counterparts. This chapter takes a close look at three studies by Root-Bernstein and goes on to try and affirm his findings by conducting and analyzing interviews with scientists that have an artistic avocation. The results of the study show that art offers an escape for scientists to reorganize their thoughts. Further, if scientists combine the two worlds of art and science, the scientists can directly benefit from their artistic avocation for their scientific work.

DOI: 10.4018/978-1-5225-9188-7.ch004

INTRODUCTION

To summarize the task of scientists is easy in the first instance. It is the solving of scientific problems. But, from a working perspective of a scientist, this is twofold because it refers to gathering (new) knowledge qualitatively or quantitatively, and it points to outlining the research matters towards an academic audience and students. And from a success-perspective, actually designing, conducting and publishing research asks for a multitude of skills and capabilities. This demand for versatility, multiperspectivity and creativity resonate with the abilities needed to actually realize the fourth industrial revolution and create technologies that fuse the physical, digital and biological world (Schwab 2017, Schwab, Davis & Nadella 2018), automatizing simple task and creating the potential and opportunity to unleash creativity. To foster this potential for further innovation it is essential to investigate successful individuals, like inventors, creatives, artists and innovators. Focusing on successful scientists with secondary artistic vocation we investigate in a qualitative study the phenomenon of modern polymaths, in particular how they perceive their interests relate and whether the artistic vocation fosters their scientific work. Research on polymaths, multiple vocations and scientific success was introduced and popularized by Robert Root-Bernstein.

He studies the linkage between artistic avocation and scientific success. The findings indicate that an artistic performance and production of a person impacts the scientific performance and production of him or her in a positive way. The challenges a scientist faces, such as creating new knowledge, teaching students, and inspire a future generation, experience enrichment in different ways because of the scientist's art expertise. Thus, if a scientist can develop new skills that impact how he or she teaches, inspires, or expresses knowledge for a future generation it is worth to investigate in this positive combination because this is highly required in the fourth industrial revolution.

And he also found a positive impact of the scientific skills and performance on the artistic activity. Being able to reflect on issues, orientate on critical matters and to express complex issues to less informed individuals are typical scientific skills that foster the artistic avocation. On a broader perspective, people, who have dealt with a variety of different things, do once combine all their findings and create some great pieces of art, such as Leonardo DaVinci or the creator of everything around "Jurassic Park" (Hartford, 2019). Although we teach our children to focus on particular things to improve, engagement in a variety of interests can, in a longer run, create great science and art or, more generally expressed, expertise and perfection and thus inspiration, orientation, and vision.

This chapter contributes to the discourse on the fourth industrial revolution by focusing on how to foster the research and innovation capabilities by studying the link between artistic avocations and scientific work qualitatively. The topic of this study is the verification of theses made by Robert Root-Bernstein whose various studies substantiate the argument that a scientist who is artistically active is a more successful scientist. The work of Robert Root-Bernstein is prominently featured in this study. His work laid the foundation for this field of research and is still the most comprehensive on this matter today. Therefore, a thorough introduction of his work is presented in the first part of this chapter. His theses were reevaluated conducting four semi-structured quasi-narrative expert interviews with scientists who have an artistic avocation. Those interviews were then analyzed by using the seven steps for qualitative evaluation by Kuckartz, Dresing, Rädiker & Stefer (2008) and after that, the findings from the interviews are compared to findings from Root-Bernstein and whether or not the interviews can verify his claims. The chapter is structured as follows. First, some examples for scientists that are also artists are given, then three essential studies by Robert Root-Bernstein are described. After that, the methodological setting, as well as data and results, follow. The chapter ends with a discussion of the results and limitations to the study.

BACKGROUND

Before we dive into the theoretical aspects important for this chapter, some general definitions have to be made. The Oxford Dictionary defines art, or the arts, as "the various branches of creative activity, such as painting, music, literature, and dance". An artist is, therefore, a person who practices or performs any of those art forms. Art encompasses the production of a piece of art as well as a piece of artwork itself, and art is also considered as a source of knowledge. Freelander (1997) outlines the relation of art and cognition comprehensively: "(1) Artworks stimulate cognitive activity that may teach us about the world. (…) (2) The cognitive activity they stimulate is part and parcel of their functioning as artworks. (3) As a result of this stimulation, we learn from artworks: we acquire fresh knowledge, our beliefs are refined, and our understanding is deepened. (4) What we learn in this manner constitutes one of the main reasons we enjoy and value artworks in the first place." Art stimulates the cognitive activity which leads to and fosters learning processes in a joyful and motivating way, and thus the generation of knowledge. This applies not only to the artist but also to the "consumer of the artwork", both can experience learning, knowledge creation and joy engaging in and with art (John, 2001).

Examples For Exceptional Scientists That Were Or Are Artists As Well

When one first thinks about a scientist that is also an artist and combines those two traits with each other in order to achieve even greater accomplishments and benefit from the one for the other such extraordinary geniuses come to mind as Leonardo DaVinci or Galileo Galilei. Both are seen as the quintessential example of a polymath. However, there are other, less famous examples for scientists that combine the two traits exceptionally.

One would be Albert Michelson (1853 - 1931). Michelson was an American physicist and is most famous for developing a precise method to measure the speed of light (Root-Bernstein, 2006). For this he received the Nobel Prize in physics in 1907, becoming the first United States citizen to achieve this honor. A lesser known fact about Albert Michelson is that he had an avocation in arts. He was a painter and did achieve some significant success with that. In 1928 he had a solo exhibition at the University of Chicago (Root-Bernstein, 2006). A biography written about him in 1973 quoted him by saying “I did not have to choose [between art and science] because for me they are inseparable” (Livingston, 1973, p. 322), giving an idea of the influence that his avocation of painting has had on his scientific achievements that without a doubt are extraordinary.

Another example of a polymathic scientist that let his work be influenced by art was the German physicist Max Planck (1858 – 1947). He is most famous for being the inventor of the quantum physics and for this he was awarded the Nobel Prize in physics in 1918. However, before fully committing his career to science he considered making his musical passion into a living (Root-Bernstein, R. S. & Root-Bernstein, M. M., 2004, p. 10). Planck was an exceptional pianist and at one point planned to make a career out of it. In an autobiography, published two years after his death, Planck says something that very much mirrors the aim of this paper: “A pioneering scientist must have an […] artistically creative imagination” (Planck, 1949, p. 109), making him, as well as Michelson, the perfect example to present in this section.

Two recent examples of living scientists who also engage in arts are presented. One is Michael Hassemer, born in 1966 and chair holder at the Kaiserslautern University of Technology in Germany. Additionally, to his professorship, Hassemer is also a member of the Rhineland-Palatinate constitutional court. On the other hand, Hassemer is also a passionate musician who plays in two bands, has published several albums and has his own recording studio in the basement of his home.

A second more modern example of a scientist and artist is Andreas König, chair holder at the University of Passau, Germany. He is published in journals such as Academy of Management Review, Academy of Management Journal or Research Policy and, additionally to his chair in Passau, is an affiliate research fellow at the

International Institute for Management Development in Lausanne, Switzerland. However, previous to studying business König got Bachelor's and Master's degrees in music. After that, he played professionally for several years in an orchestra as well as a solo artist. He says that his work as a scientist and lecturer are influenced by the experiences he made during his time as an active musician.

At the theoretical cornerstone of this essay are the American scientist Robert Root-Bernstein and his studies into the correlation between artistic avocation and scientific success. Root-Bernstein is a professor at Michigan State University in the United States. Over the years his research focus has been the impact that artistic avocation has on the career success of a scientist. Three of his papers shall be discussed in more depth as they are essential for the theoretical setting of this paper and the following study.

Root-Bernstein et al. (1995)

The first paper by Robert Root-Bernstein that will be looked at closer within this essay is his 1995 work "Correlations between Avocations, Scientific Style, Work Habits, and professional Impact of Scientists" in collaboration with Maurine Bernstein and Helen Garnier. The authors use a set of data collected by Bernice Eiduson, a psychology professor from UCLA, who conducted a series of interviews and different psychological tests between the years 1958 and 1978 (Eiduson, 1960; Eiduson, 1966a; Eiduson, 1966b, Eiduson & Beckmann, 1973). The sample consisted of 40 male scientists who were spread fairly wide over different fields of science such as physics, biology or chemistry. For their study from 1995 Root-Bernstein and his co-authors, Maurine Bernstein and Helen Garnier recycled the findings from Bernice Eiduson and added more data to the already existing information, in order to get more insights specific to the research question. Particularly, the authors sent out a questionnaire to those 38 scientists still alive in 1988 questioning in depth the scientists' style of thinking, hobbies and other physical activities.

The study also considered the scientific success the 40 scientists were able to achieve during their career. In order to measure scientific success, the authors analyzed the scientists' publications and how often they got cited. They, therefore, decided on four groups ranging from the scientists with one or more papers cited at least a 100 times during 1964 and 1978 in the highest "success" group, to those with no paper cited at least ten times as the fourth group. In addition to the citation cluster, the authors collected an impact ratio which stood for the total number of citation during the years from 1964 until 1978 divided by the author's total number of publications during the same time period. In order to achieve results that help answer the research question, whether artistic avocations have an impact on scientific proficiency, Root-Bernstein et al. (1995) correlate the findings of the questionnaire with the impact ratio and the citation ratio.

They found that painting and drawing are significantly correlated with high impact and high citation clusters. Other creative hobbies such as poetry, creative writing or photography were significantly correlated with the citation cluster but not with the impact cluster. This indicates that successful scientists appear to be engaged in the fine arts more often than their not as successful counterparts. The authors also found a correlation of both measures with scientists that use visual forms of thinking. This implies for Root-Bernstein et al. (1995) that successful scientists appear to “see” their findings within their mind. Interestingly also less successful scientists in the study sometimes engaged in as many activities as their more successful counterparts. Root-Bernstein et al. (1995) explain this discrepancy as that those less successful scientists failed to combine the two worlds with each other. They did not try to integrate the artistic way of thinking into their scientific work as many of the other more successful scientists did as described in the interviews from Eiduson’s study. The authors, therefore, stress the importance of making a connection between the two worlds of art and science. Simply being an artistically active scientist does not help ones’ scientific success, but integrating artistic ways of thinking into the process appears to have an impressive impact on one’s scientific career.

Root-Bernstein, R. S. & Root-Bernstein, M. M. (2004)

In the second paper from 2004 “Artistic Scientists and Scientific Artists: The link between Polymathy and Creativity” Robert and Michele Root-Bernstein argue against the following statement by C.P. Snow:

Between the two [arts and science] a gulf of mutual incomprehension – sometimes […] hostility and dislike, but most of all lack of misunderstanding. […] Their attitudes are so different that, even on the level of emotion they can’t find much common ground. (Snow, 1964, p. 4).

They argue against Snow’s argument by offering five different types of evidence that aim to prove that his way of thinking is not correct and that in fact art and science “are part of one, common creative culture largely composed of polymathic individuals” (Root-Bernstein, R. S. & Root-Bernstein, M. M. 2004, p. 128).

The first argument the authors offer is that successful artists and scientists more often than not are interested in and are good at more than one subject that crosses transdisciplinary borders and heightens their success in their core discipline. For this, the authors provide examples similar to those that were discussed in an earlier section of this paper. Therefore, no further examples will be given here.

As a second source of support for their thesis of one common culture between art and science, Root-Bernstein & Root-Bernstein (1995) argue that artists and scientists share similar psychological profiles. This comes from an earlier study from Bernice Eiduson who compared psychological profiles of businessmen, scientists, and artists (Eiduson, 1962; Eiduson, 1966a; Eiduson & Beckmann 1973; Root-Bernstein, Bernstein & Garnier, 1993). She found out that profiles from artists and scientists could not be clearly differentiated. This leads the authors to propose that "scientists and artists may be being drawn from a single pool of talent" (Root-Bernstein, R. S. & Root-Bernstein, M. M. 2004, p. 136).

As the third set of evidence, Root-Bernstein & Root-Bernstein (2004) argue that art avocations do in fact predict scientific success. As Terman, initiator of the long-running Genetic Studies of Genius said in response to a study by one of his students "there are few persons who achieved great eminence in one field without displaying more than average ability in one or more other fields" (Seagoe, 1975, p. 221). The authors reference a, at the time, a more recent study by Milgrim, Hong, Shavit & Peled (1997) which offers support for this thesis as well. It appears that polymathy, in general, is correlating with career success. Root-Bernstein & Root-Bernstein (2004) found that "scientist who made or collected art, who practiced photography, or who were active as musicians, were much more likely than their colleagues to produce one or more papers cited 100 or more times within fifteen years or papers cited ten or more times in a single year" (Root-Bernstein, R.S. & Root-Bernstein, M. M. 2004, p. 138). The authors propose that not only do artists and scientists share psychological traits but that a lot of the times scientists actually *are* artists as well as scientists.

The fourth type of evidence that supports Root-Bernstein & Root-Bernstein's thesis that art and science share a culture is the finding, that artists and scientists often use the same words to describe their ways of thinking and problem-solving. The authors go on to quote artists and scientist and how they similarly describe those ways of thinking. They conclude that "the individuals' choice of public discourse is what determines the domain to which his or her ideas contribute rather than the way in which the ideas are initially conceived" (Root-Bernstein, R. S. & Root-Bernstein, M. M. 2004, p. 145). Meaning that for example, Einstein solved his physics problems through images and muscular feelings and later "translated" or "transformed" those into actual findings that others could understand.

The fifth and final part of the evidence they bring forward supporting the thesis of a common culture between the arts and science is that science appears to foster better art and art appears to foster better science. They argue that on the one hand science has had an impact on art by for example color theory or the development of new techniques but on the other hand, art also has an influence on science. The first Morse telegraph, for example, was constructed with the help of a canvas stretcher adapted from the scientists' painting days. The authors conclude this chapter of their essay with a fitting summary of the evidence they put towards rebutting C. P. Snow's two cultures theory: "artistic and scientific thinking are not two different kinds of cognitive activity, but two aspects of the same creative impulse" (Root-Bernstein, R.S. & Root-Bernstein, M. M. 2004, p. 149).

Root-Bernstein et al. (2008)

The third theoretical paper co-authored by Robert Root-Bernstein is from the year 2008 and titled "Arts Foster Scientific Success: Avocations of Nobel, National Academy, Royal Society, and Sigma Xi Members". In it the authors put the theories and hypotheses they proposed in earlier papers to the test and compare several groups of scientists with each other to find out whether artistic avocation or activity has a positive effect on the career success of the scientist at question. For this study Root-Bernstein and his 14 colleagues, Honors students from Michigan State University, compared Nobel Prize winners, obituaries and memoirs from the Royal Society, biographical memoirs from the National Academy of Sciences, a 1936 avocation survey from members of the Sigma Xi Society and a 1982 survey of arts avocations within the United States public by correlating them.

Within the scientific world, the Sigma Xi Society can be seen as the most general platform, as every scientist can become a member through the nomination by two other members of Sigma Xi (Sigma Xi). The Nobel Prize winners are the most elite group, as the Nobel Prize is the most prestigious award a scientist can achieve for his work and only one award is handed out per scientific field and year. By comparing the different groups, the authors found that the Sigma Xi respondents averaged 0.33 avocations in arts, while the general US public averaged 0.35, the members of the Royal Society 0.59, members of the National Society of Sciences 0.56 and the Nobel Prize laureates 0.94 arts avocations on average. This means that Nobel Prize winners were almost 300% more likely to have an avocation in arts than Sigma Xi Society members or the general US public. They were also 50% more likely to have such an avocation than members of the National Academy of Sciences or the Royal Society (Root-Bernstein et al., 2008, p. 53).

Another interesting finding is that the more "exotic" an avocation is the more likely is it that a Nobel Prize winner practices it in comparison to an "average" scientist. While they are only at least as likely to practice photography in their spare time, a hobby that at the time of publication in Spring of 2008 57.58 million Americans practiced (Statista.com), Nobel Prize winners are at least twelve time more likely to write poetry or plays than the average scientist (Root-Bernstein et al., 2008). The authors conclude their analysis by pointing out that "very successful scientists are much more likely to be polymaths than the average scientist" (Root-Bernstein et al., 2008, p. 55). Another interesting factor that the findings allege is that it appears that contrary to popular belief a higher specification in one field does not imply better achievements in that field but actually, the more diverse one's interests are it actually enhances ones' achievements in its core scientific work. As a scientist learns from artistic avocations it appears to help the scientist to achieve even greater success and acclaim. The authors also discuss at depth how scientists through all fields combine their artistic avocations with their scientific work in order to achieve greater things.

Other Literature

Of course, there are other authors who have looked at a connection between art and science, art and technology, or art and innovation. In order to consider some alternative approaches and to offer a different opinion to that of Robert Root-Bernstein, a short overview of other theoretical concepts follows.

Stüer, Hüsig and Biala (2010) looked into the inclusion of artists into the radical innovation process. They see that artists foster creativity and transdisciplinarity, as well as challenge existing patterns and routines. Artists think outside the box and across borders, which puts them close to R&D employees, whose job is to think innovative and find new, uncommon ideas in order to advance their company and give them an edge over their contenders. Stüer et al. (2010) therefore propose the addition of artists into the R&D process. This is a different approach than the one Root-Bernstein took, by not limiting the influence that art may have to the science but rather open it further to include companies and how they can benefit from art.

Feist conducted a meta-analysis of personalities in scientific and artistic creativity in 1998. For that, he compared empirical results from several studies by using the Five-Factor Model dimensions on personality. These five factors are neuroticism, extraversion, openness, agreeableness, and conscientiousness. He compared studies that regarded themselves with scientists versus non-scientists, creative scientists versus non-creative scientists and artists versus non-artists. Some of his findings interesting to this paper are that creative scientists are understood to be "more aesthetically oriented, ambitious, confident, deviant, expressive, flexible, intelligent, and open to new experiences than their less creative peers" (Feist, 1998, pp. 296-298). When comparing artists to non-artists Feist found that artists were, amongst other things, more "creative, curious, imaginative, [and] open to experience" (Feist, 1998, p. 298), all of which arguably are characteristics a scientist may profit from. However, Feist, other than Root-Bernstein, does not argue that artists and scientists share personality profiles but rather differ in that regard based on his findings (Feist, 1998, p. 299).

Robert Root Bernstein himself has more recent studies that still regard themselves with correlations between art and science in a broader way. He researched the way that arts, crafts, and design can improve the way that the so-called STEMM subjects (science, technology, engineering, mathematics, medicine) can be learned and provide a more successful career in those subjects (Root-Bernstein, Pathak, Root-Bernstein, 2017). In a follow-up study from 2019 Root-Bernstein ran a survey in which he and his co-author sent out a survey to STEMM professionals, in order to detect which tools for thinking, previously identified, lead to success. Some of those tools for thinking can be taught through artistic avocations. Interestingly, the participants were aware of the connection between their STEMM work and their artistic avocation, which leads to the conclusion that they consciously chose to be artistically active in order to enhance their work (Root-Bernstein, Van Dyke, Peruski & Root-Bernstein, 2019).

Research Gap and Research Question

While other literature was looked into, the theoretical cornerstone of this study was Robert Root-Bernstein's work. His research conducted over decades was able to find support for his thesis that an artistically active scientist is a more successful scientist. However, his research was limited to scientists from the United States and the United Kingdom. The aim of this study is to review his findings by conducting a number of interviews with German-born scientist and verify his hypotheses through those interviews and potentially identify new aspects, not looked into by Root-Bernstein, but worth looking into for future research agendas. The sample in this study differs in some ways from the sample used in Root-Bernstein's studies. For one the interviewees are younger than those interviewed for Root-Bernstein's study, and second, the interviews by Root-Bernstein were conducted between 1958 and 1978. Also, the study focuses on three scientists who regard themselves with management science, while Root-Bernstein focused mainly on natural sciences such as chemistry and physics. The German origin of the scientists is also a strength of the study, as it adds another layer to the research by looking at a nationality that is not reflected by Root-Bernstein. Specific elements from each of the papers by Root-Bernstein presented in this chapter shall be kept in mind for the interviews and subsequent analysis of those interviews in order to verify the claims by Root-Bernstein regarding artistic avocations and scientific success.

From the 1995 paper, it will be interesting to see whether the interviewed scientist try to integrate and connect the two worlds of art and science as proposed by Root-Bernstein et al. (1995) in order to integrate artistic ways of thinking into their scientific process. Regarding the 2004 paper by Root-Bernstein & Root-Bernstein, it will be interesting to see whether or not some of the five arguments can be verified within the conducted interviews. The 2008 paper somewhat gives the research question for this paper as Root-Bernstein et al. find empirical support that Nobel Prize winners are more likely to have an artistic avocation than less successful scientists. To make such a statement will be hard to make for this study as there will not be a control group of scientists who do not have an artistic avocation. This study aimed to find out whether or not the interviewed scientists see a connection between their artistic avocation and their scientific work or whether those two are entirely different to them by interviewing them and can by that verify Root-Bernstein. The research question this study tries to answer is, therefore: Can the findings by Robert Root-Bernstein be verified for German scientists as well, implying a general and not context- or culture-specific correlation?

METHODOLOGY

In order to gain insight and shed light on the question of whether artistic avocation has a positive influence on scientific prosperity, the following study is based on qualitative interviews. Such qualitative interviews offer a good insight into the field and are often used as preparation for follow up standardized quantitative studies (Hopf, 2004). Interviews were also one of the chosen methods of Robert Root-Bernstein in the earlier described papers he and his co-authors published over the years. However, the interviews he references are mainly not conducted by him and the youngest set of interviews is from 1988 (Root-Bernstein et al., 1995). In their 1995 paper, the authors also admit that a large portion of the interviews "were not sufficiently detailed or did not address certain issues of interest to the present study" (Root-Bernstein et al., 1995, p. 119). Therefore, in order to come to conclusive and insightful findings, qualitative interviews appear to be the right methodological setting.

The interview shall not follow a standardized plan but more of a semi-structured setting as this allows the interviewer and interviewee to dive into personal and social matters (DiCicco-Bloom & Crabtree, 2006) in order to find out whether and if, how art has had an influence on a scientists' career. Also, semi-structured interviews are frequently used as the only source of data in a study project and can stand on their own without having to be supported by other methods (DiCicco-Bloom & Crabtree, 2006). As the interviews are the only data collected and analyzed it makes perfect sense to rely on semi-structured qualitative interviews as the sole data source for this research project.

This study follows a methodology developed by Kuckartz et al. (2008) called the qualitative evaluation in seven steps. Their aim with this method was to find out whether qualitative evaluations under strict time restrictions could still gain reliable results while proposing a manual for efficient and effective use of qualitative methods that are applicable not only in theory but rather in practice (Kuckartz et al., 2008, p.13). The seven steps the authors proposed are the following:

- The object of evaluation and goals of evaluation,
- Interview guide and development of the questionnaire,
- Conducting, recording and transcription of the interviews,
- Data scouting, ad hoc presentation,
- Developing a category system and coding the interviews,
- Analyzing category based and producing the evaluation report, and
- Working out a summary, reporting results, finishing the study.

While not all seven steps were followed to the last degree, they structured the basic research design underlying this study. For example, the authors used computer software to analyze and code the interviews, but in this study all coding and analyzing has been done without the help of a computer, also the proposed questionnaire from step 2 was not conducted due to reasons described below.

DATA AND RESULTS

The following paragraphs regard themselves with the data collection and analysis of this study. The seven steps proposed by Kuckartz et al. (2008) are introduced and it is described how they were carried out, allowing to comprehend, reconstruct, review and test the presented process of data gathering.

Step 1: Object of Evaluation and Goals of the Evaluation

The first step of the seven steps of qualitative evaluation as described by Kuckartz et al. (2008, pp. 16-20) calls for the establishment of the object of evaluation as well as the goals of the evaluation. The object of evaluation in this project are interviews conducted to support the studies by Robert Root-Bernstein and colleagues that claimed and found empirical support for the thesis that a scientist with an artistic avocation is a better, more successful scientist than their non-artistic counterparts. Their theories are well explained in previous chapters of this study. The evaluation will be conducted through interviews with scientists that also have an artistic avocation. The goals of the evaluation align with the objects in a way that the author wants to find out whether the questioned scientists can support Root-Bernstein and his theory that an artistic avocation does have a positive influence on scientific achievements and to report on their personal experiences.

Step 2: Interview Guide and Development of the Questionnaire

Step two of the seven steps for qualitative evaluation by Kuckartz et al. (2008, pp. 20-23) is the development of an interview guide, as well as a short questionnaire. In this case, the conducted interviews are narrative expert interviews with the aim to collect information (Bogner, Littig & Menz, 2014). The questioned scientists are experts in their fields as well as their lives and can, therefore, explain the influence their artistic avocation has had on their scientific career. The interviews followed a semi-structured setting in order to allow the interviewee to answer freely and in order to not be limited to a strict pattern of questions. It is the authors' goal to gain insight into the influence that artistic avocations of any kind have on scientific success and that the interview is like a conversation in which the interviewee is encouraged to share their experiences.

The interviews can be classified as narrative interviews as the interviewed is asked to offer an insight into their personal life experiences (Hopf, 2004). While the author did have a range of potential questions prepared not every question prepared had to be posed, because the interviewee tackled the question on their own. No interview was the same to the others, as all were largely guided by the answers given by the interviewee. We relied on the open-ended question in order to gain additional understanding, information and attitudes of the research object and to generate a genuine conversation by keeping the conversation flowing. The questions, as well as the interviews, were conducted in German.

The other proposed aspect in step two of the qualitative evaluation by Kuckartz et al. (2008) is the preparation of a short questionnaire. This step was not fulfilled for this project, as the socio-demographic data was no relevance for this study.

Step 3: Conducting, Recording, and Transcription of the Interviews

The third step within the seven steps for qualitative evaluation by Kuckartz et al. (2008, pp. 24-32) calls for the conduction, recording, and transcription of interviews. Four interviews were conducted. As it was essential that all interviewees were scientists and had an artistic avocation, the potential sample size was rather small, to begin with. The sample can be described as a theoretical sample, more specifically a homogeneous targeted sample, as the interviewees were found through two recruiting ways and the sample was relatively small (Döring & Bortz, 2016, p. 304). The recruiting was conducted using personal as well as professional networks to find suitably interview partners, i.e. scientists with an artistic avocation. Personal network in the means of family and friends, as well as the professional network of the chair, was used to identify and select scientists who fit the description. These selected individuals were then contacted via email. One scientist that was identified and selected using the professional network, a professor with his own chair at a German university, agreed to be interviewed. Using the personal network another professor, who is of German descent but lives and works in the United States was identified and selected as well as two Ph.D. students, one industrial doctorate and the other a scientific assistant at a chair at a German university.

There were three male interviewees and one female. Three of the interviewees work in business and or management while the fourth holds a chair at the school of kinesiology at an American University. One of the professors is a studied trumpet player who has played in big orchestras, as well as solo performances. The other plays the violin but rather as a hobby and started late in his life with his musical avocation. The industrial Ph.D. student writes screenplays for movies and the other Ph.D. student writes poems, has a blog and does crafts. The interviews were conducted at different points in time and via different mediums. The two Ph.D. students were interviewed face to face, while the other two interviewees were spoken to via telephone. All interviews were conducted at fitting points in time when both parties were available. All four participants were contacted in prior and asked for their participation and all were immediately willing to do so. All interviews were recorded with the consent of the interviewee using the voice memo app on the authors' iPhone.

The interviews lasted between ten and 25 minutes depending on the interviewees' time and information regarding the topic. The first interview, put in order by date of recording, lasted for 15 minutes and 18 seconds, the second for 14 minutes and 51 seconds, the third for 25 minutes and 31 seconds while the fourth and final interview lasted for nine minutes and 25 seconds. After conducting the interview, all interview recordings were transcribed using transcription software. Due to the software, the audio files could be slowed down or sped up as necessary. The interviews were transcribed with the textual semantical transcription system which is rather simple but brings across the speakers' intention and is fully sufficient for the analysis of this project.

Step 4: Data Scouting, Ad Hoc Presentation

Step four of the qualitative evaluation in seven steps approach from Kuckartz et al. (2008, pp. 33-35) calls for a first scouting of the data collected. For this, the transcribed interviews are read and striking points are highlighted, comments are written down and first ideas for potential categories are formed (Kuckartz et al., 2008, p. 33). The authors propose to give each interview a characteristic title that sums up the interview and each interviewee as perfect as possible. This tactic was also applied for this evaluation as it highlights each interviewee for his or her significant characteristics and makes it easier in the upcoming analysis to reference single interviews.

The first interviewee, organized in order of recording, is characterized as *the free-living screenwriter*. This is the industrial doctorate and he described himself as a free-living screenwriter and said that that aspect is what he enjoys most about his artistic outlet, leading to this fitting characteristic summary. The second interviewee was the other Ph.D. student, who is given the description of *the creative escapee*. She has multiple creative, artistic outlets that she chooses to escape to depending on the situation and one cannot clearly define her one specific artistic avocation. Thirdly, there is *the professional*. The management chair holder from Germany, who has a master degree in trumpet and played concerts all over the world in orchestras, as well as a solo artist. He, by far is the most professional artistically active scientist in the group, leading to this characteristic summary. The fourth and final interview partner was the German-born professor from the United States. As he only started playing the violin in his forties, therefore, leading to him being titled *the late bloomer.*

Step 5: Developing a Category System and Coding the Interviews

The fifth step as described by Kuckartz et al. (2008, pp. 36-43) calls for the development of a category system and to then code the interviews to fit into those categories. For every qualitative evaluation, there has to be a different category system fitting to the evaluation goal and the findings within the interviews. For this evaluation, there are four categories which were selected to be the main evaluation categories as they were found in at least three if not all four interviews. The first category is the influence that the artistic avocation has on the interviewee's scientific work. This is somewhat the essence of this entire study project and therefore must be recognized with its own category.

Even though no two interviews took an identical course, in every interview this question was posed and answered and therefore an evaluation based on this category could be realized. Another question all interviewees were asked was what each individual would be missing from their life if they did not have art in their life. Each answer gives a perspective on the importance their artistic avocation has in and for their lives and should, therefore, be recognized with a category. Also, as all four scientists were asked this question, there are four answers which can be compared to each other. The third and fourth categories are categories that developed by reading through the transcribed interviews and finding parallels between the points made by the interviewees. One of those categories is that three out of four interviewed scientists talked about their art being completely different from their professional occupation, an outlet or something similar. Therefore, the third category is titled: art as an escape. The fourth and final category is once again mentioned by three out of the four interviewees. All three integrate their artistic avocation or at least part of it into their scientific studies in different ways. This shows the fusion of both worlds, as also suggested by Root-Bernstein, and goes to show that through their avocation they advanced in their science. Therefore, the four developed categories are:

- *Influence of the avocation on the scientific work*
- *What would be missing?*
- *The art as an escape*
- *The integration of art into their scientific work*

The other aspect Kuckartz et al. (2008) raise for step five of their seven steps to qualitative evaluation approach is the calling for coding the interviews. Kuckertz et al. (2008, pp. 36-43) do this by coding the interviews with the help of a software. As this software was not available, we used color-coding: Each category was assigned a color and quotes that appear fitting for a category were underlined in the matching color on print outs of the transcribed interviews.

Step 6: Analyzing Category Based and Producing the Evaluation Report

The sixth step for a qualitative evaluation as proposed by Kuckartz et al. (2008, pp. 43-49) calls for a category-based evaluation of the categories highlighted in step five. They propose to analyze every category on its own and in a separate chapter which this study will follow as well.

Influence Of The Avocation On The Scientific Work

The first category relates to the influence that the artistic avocation has on the interviewees' scientific work. This touches somewhat the essence of this study, as the question it tries to answer is whether an artist is a better scientist. Therefore, all four interviewed scientists were asked whether they feel their art positively influences their scientific work. Three out of the four the agreed. The free-living screenwriter, for example, stated that he frequently uses methods in his work where he has an advantage due to his ability to write creatively as a screenwriter and that this also positively influences his scientific work. The creative escapee describes how while writing for her blog or while creating new poems, she sometimes thinks of new methodological approaches or of a different order for the passages in her scientific papers. She finds new ways on how to approach her scientific work more strategically and therefore states that her artistic avocation in that ways does influence her scientific work. She also gives three aspects in which she feels her creativity and artistic avocation help her scientific work: She approaches scientific problems rather unconventionally, she is extremely curious and inquisitive which helps her for her scientific writing, and her creativity gives her a balance which helps her not to become too uptight in her scientific work. The professional gave a sounding "yes, of course", when asked whether he feels his scientific work profits from his artistic avocation. He sees strong parallels between the two worlds of music and science and states that some of the things he learned as a musician are also relevant for him and his work as a scientist. Those things are aspects such as perfectionism, communication, patience, the ability to handle uncertainty as well as having an eye for aesthetics.

Only the fourth interviewee, the late bloomer, does not agree that his scientific work has been influenced through his artistic avocation. However, he only started playing the violin when he was already in his forties when he had already been a scientist for decades. This could be the reason why he does not feel an influence. Concluding, it appears that if a scientist is artistically active and has been since early childhood the traits one learns do have an influence on the way the scientists handle their scientific problems. In a way, it appears that art may prepare one for science, as traits you learn by being artistically active make you a better scientist. Also, all three scientists who do see a correlation work in the field of management, therefore the field in which a scientist works may influence the influence an artistic avocation has or if it has any at all. The fourth, not management related scientist, works in the field of kinesiology.

What would be missing?

The second category relates to the question, whether the scientists would be missing something from their lives if they did not have the artistic avocation in it. As all four were asked this question there are answers from all interviewees. In general, it can be said that all four of them would be missing something and none said he or she would not care if that happened. This shows that the artistic avocation plays an important part in each of their lives and the absence would have consequences. For the free-living screenwriter, he says he would be missing satisfaction and something he could be proud of. It gives him the knowledge that he can do something. He describes it to be part of his character and as part of his demeanor. The creative escapee says that she would be missing a way to express herself without having someone rate or censor it and just be completely free in writing what she feels like. She also says that while on vacation the first thing she did was to buy a diary for pouring out her soul, highlighting the importance writing has for her life and inner balance. The professional would be missing the social interaction his musical outlet gives him, as well as the feeling to be able to express himself and to create something of value. His first response to the question was “that would be quite sad wouldn’t it?” describing perfectly the way he feels about his musical avocation. Even the late bloomer who previously stated that he does not feel like his art influences his science stated that he would be missing the creative outlet of being able to do something entirely different. The four interviewees see their artistic avocation as a necessary diversion to their daily scientific work.

It appears that by switching around the question to not asking what their art does for them but rather what the interviewees would be missing if they did not have it in their lives the importance each individual feels for their artistic avocation came to light. None of the scientists would want their artistic avocation to be missing from their life, therefore they must profit profoundly from it, even if only for finding a balance for their soul.

Art As An Escape

Something that became obvious while reading through the transcribed interviews was the fact that three out of the four interviewees described their artistic avocation as something completely different, an outlet, diversion or escape from their daily, scientific life. The free-living screenwriter, for example, talked about how he does not have any deadlines, does not need to answer to anyone and enjoys the freedom his screenwriting offers him. He further declares that when he has problems with his scientific work, he sometimes likes to grab his screenplay and go a little ‘bonkers’ with it. The creative escapee also describes her writing as the possibility to do something entirely different as some sort of a balance to her scientific work. She even agrees to call it some sort of escape. The late bloomer calls art and science two different, sovereign worlds and sees his musical avocation as a creative outlet that does not have anything to do with his work but rather offers him a way to simply get away. Only the professional does not really mention something similar. While he does say that his musical avocation offers him an opportunity to get together with people who do not have a scientific background, he does not describe it as an outlet or something similar. This could be explained with his professional musical background. Maybe, the fact that he studied trumpet does not allow him to see his music as an outlet or refugee as he has different expectations for his music.

Another factor that is interesting in this regard is that both Ph.D. students have a writing avocation which does not seem to be too far removed from their scientific work. However, both do not see this as similar work but rather as completely different as mentioned above. They need their writing for balance and stress relief. This aspect shows that while maybe art does not directly influence scientific work through other aspects such as offering diversion in a stressful situation it does help to cope with stress and pressure, and thus, in the long haul.

The Integration of Art into the Scientific Work

The last category relates to the integration of art or artistic elements into the scientific work of the interviewees. This once again was an aspect that came up during reading the already conducted and transcribed interviews. Three out of the four interviewees offered examples of how they integrated aspects of their art into their scientific work. The free-living screenwriter methodically included creative writing aspects into his work, while the two professors both had or have scientific studies which include musical aspects. The professional recently started a study into musical conservatories, while the late bloomer already completed a study regarding the way that small children learn to play the violin. This shows the fusion of both worlds. Through the artistic avocation new, interesting scientific studies emerged and gave the scientists the opportunity to profit from their art for their professional careers and enhance their scientific success.

Step 7: Working out a Summary, Reporting Results, Finishing the Study

The seventh and final step Kuckartz et al. (2008, pp. 50-58) describe in their qualitative evaluation manual asks for working out a summary as well as reporting the results and finalizing the study. The goal of this evaluation was to find out whether Robert Root-Bernstein's' thesis, that an artistic avocation does have a positive influence on a scientists' work can be confirmed. Three out of the four interviewed scientists did agree that their artistic avocation does positively influence their scientific work, offering further support for the thesis by Root-Bernstein. But there were also other aspects that came to light during the interviews and subsequent analysis. The scientists described their artistic avocation as something different, a diversion, an outlet, hinting that while their art may not (only) directly but also indirectly influence their scientific achievements as they offer them the opportunity to flee into another world and emerge with newfound powers from there in order to focus on their science once again. This aspect of positive distraction, diversion or escapism was consistent throughout all interviews. Lastly, three out of the four scientists incorporated aspects of their artistic avocation into scientific projects. This shows that not only does the science profit from the scientists' artistic avocation but sometimes science emerges from art and thereby offers the scientists new exciting approaches to research they might not have looked into if they had not stumbled upon them through their art.

REFLECTION & CONCLUSION

After the analysis of the interviews in the previous chapter, let's go back and link the results to the literature by Root-Bernstein and see whether or not this study can affirm his findings as described earlier. As for the first paper described, this study supports the positive combination of the two worlds art and science. Three out of the four interviewees integrate their artistic avocation into their scientific work merging the two worlds voluntarily in order to benefit directly from their artistic avocation allowing us to verify Root-Bernstein.

Regarding the 2004 paper by Root-Bernstein and Root-Bernstein, some of the arguments can be verified through the interviews. The professional offered a convincing argument as to why art and science do share the same culture and that the characteristics you need for one are also important for the other. They argue that science fosters better art and vice versa. As described above three out of the four interviewed scientists integrate artistic elements into their scientific work, offering support for their thesis. In conclusion, this study, with the goal to examine the thesis by Root-Bernstein that an artist is a better scientist, does indeed find support for his claims.

The 2008 paper by Root-Bernstein et al. uses a quantitative approach by correlating data collected from scientists of different acclaim with and without an artistic avocation, as well as the general public in order to figure out whether or not those scientists with an avocation are more successful than those without. Such correlations are not possible with the data collected for this study. Since three out of the four interviewees agree that their artistic avocation influences their scientific work, Root-Bernstein's thesis can at least tentatively be verified.

Additionally, the authors also talk about how scientists combine their artistic talent with their scientific work, which, as has been thoroughly discussed, can be verified through the interviews conducted for this study. Taken together one can answer the research question "can the interviewed scientists verify the findings by Robert Root-Bernstein through qualitative interviews?", with a tentative yes. While empirical correlations cannot be measured with this qualitative study, the interviewees do give room to verify the hypotheses by Root-Bernstein and his colleagues regarding the influence that artistic avocations have on scientific work and its success. Specifically, three assumptions can be made:

- If a scientist is artistically active and, even better, has been since childhood, the artistic avocation can have an influence on the manner one handles their scientific problems.
- Art offers an escape from the daily scientific work, during which the scientists are able to get away from potential scientific problems, to reorganize their

thoughts and potentially find new solutions or approaches in an indirect manner.

- If a scientist actively combines the two worlds of science and art, scientists can directly benefit from their artistic avocations for their scientific work.

As with every scientific work, this one also has several limitations. The most obvious one, in this case, is the rather small sample size of interviews. While this was also expected by the choice of sampling method, it did not make it possible to empirically verify the thesis by Robert Root-Bernstein. This was even more so a factor as there was no control group of scientists who did not have an artistic avocation.

There are several possible and sensible ways to go from here. One is to deepen the current avenue of research by collecting more data as well as a control group in order to allow empirical testing through correlations. Other future inquiries may include research that follows Root-Bernstein (1995) focusing on specific fields of scholarly or artistic activity and profession, aiming to find out whether there are fields of scientific and artistic profession and activities, that e.g. correlate more effective or that show more or less impact in combination with a respective avocation in general. The aspect of "exoticism" regarding the specific artistic avocation and whether it correlates with the scientific performance (mentioned by Root-Bernstein et al., 2004) seems also quite worth a modern and deeper investigation, e.g. a triangulated approach or a longitudinal study following individuals that stepped into both worlds, science, and arts, but at different times of their life and with different emphasizes. The categories presented in this study, e.g. the late-bloomer, the professional and the creative escapee, may support sampling individuals for such a quantitative investigation.

But the findings do not only have implications for science but can also be taken to other spheres such as management, in particular research and development. In respect to the findings, it could be beneficial to foster art in any form for the employees and thereby enhance their work. Another potential implication would be to consider the artistic activity of job applicants. If an avocation in arts fosters better science it would be good for companies to hire employees with an artistic avocation and benefit from their polymathic talents.

Concluding, it can be said that for scientists who have an artistic avocation it is important to try and combine the two worlds of art and science into one collective world in which one can benefit from the other. To foster this relationship and reap in its benefits through impressive scientific work should be of importance for universities and research institutions or departments in general. This study alludes to the phenomenon that active members of both worlds that regularly combine them, often claim that it broadens their horizons and increases the scope and activity of their imagination and creativity.

REFERENCES

DiCicco-Bloom, B., & Crabtree, B. F. (2006). The Qualitative Research Interview. *Medical Education*, *40*(4), 314–321. doi:10.1111/j.1365-2929.2006.02418.x PMID:16573666

Döring, N., & Bortz, J. (2016). *Forschungsmethoden und Evaluation*. Heidelberg, Germany: Springer.

Eiduson, B. (1960). The Scientist's Image of himself. *Science*, *132*(3426), 552–554. doi:10.1126cience.132.3426.552-a PMID:17798831

Eiduson, B. (1962). *Scientists. Their Psychological World*. New York, NY: Basic Books.

Eiduson, B. (1966 a). Productivity Rate in Research Scientists. *American Scientist*, *54*, 57–63. PMID:5907922

Eiduson, B. (1966 b). Scientists as Advisors and Consultants in Washington. *Bulletin of the Atomic Scientists*, *22*(8), 26–31. doi:10.1080/00963402.1966.11454975

Eiduson, B., & Beckman, L. (1973). *Science as a Career Choice*. New York, NY: Russell Sage.

Feist, G. (1998). A Meta-Analysis of Personality in Scientific and Artistic Creativity. *Personality and Social Psychology Review*, *2*(4), 290–309. doi:10.120715327957pspr0204_5 PMID:15647135

Freeland, C. A. (1997). Art and moral knowledge. *Philosophical Topics*, *25*(1), 11–36. doi:10.5840/philtopics19972518

Hartford, T. (2019). *A powerful way to unleash your natural creativity*. Retrieved from https://www.ted.com/talks/tim_harford_a_powerful_way_to_unleash_your_natural_creativity/transcript?language=en

Hopf, C. (2004). Qualitative Interviews - ein Überblick. In U. Flick, E. V. Kardoff, & I. Steinke (Eds.), Qualitative Forschung. Ein Handbuch (pp. 349-360). Reinbeck bei Hamburg: Rowohlt.

John, E. (2013). Art and knowledge. In The Routledge Companion to Aesthetics. New York, NY: Routledge.

Kuckartz, U., Dresing, T., Rädiker, S., & Stefer, C. (2008). *Qualitative Evaluation: Der Einstieg in die Praxis*. Wiesbaden: Springer Verlag.

Livingston, D. (1973). *Master of Light: A Biography of Albert A. Michelson*. New York, NY: Scribner.

Milgrim, R. M., Hong, E., Shavit, Y. W., & Peled, R. W. (1997). Out of School Activities in Gifted Adolescents as a Predictor of Vocational Choice and Work Accomplishment in Young Adults. *Journal of Secondary Gifted Education*, *8*(3), 111–120. doi:10.1177/1932202X9700800303

Planck, M. (1949). *Scientific Autobiography and Other Papers* (F. Gaynor, Trans.). New York, NY: Philosophical Library. (Original work published 1948)

Root-Bernstein, R., Pathak, A., & Root-Bernstein, M. (2017). (Accepted)). A Review of ACD-STEMM Integration, Part 3: Controlled Studies of Additional Transdisciplinary Bridges for Arts-Science Pedagogy and General Conclusions. *Leonardo*. *Just*, 1–3.

Root-Bernstein, R., Van Dyke, M., Peruski, A., & Root-Bernstein, M. (2019, February 5). Correlation between tools for thinking; arts, crafts, and design avocations; and scientific achievement among STEMM professionals. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(6), 1910–1917. doi:10.1073/pnas.1807189116 PMID:30718388

Root-Bernstein, R. S. (2006). Art Science: The Essential Connection, Albert Michelson, Painter of Light. *Leonardo*, *39*(3), 232. doi:10.1162/leon.2006.39.3.232

Root-Bernstein, R. S., Allen, L., Beach, L., Bhadula, R., Fast, J., Hosey, C., ... Weinlander, S. (2008). Arts Foster Scientific Success: Avocations of Nobel, National Academy, Royal Society, and Sigma Xi Members. *Journal of Psychology of Science and Technology*, *1*(2), 51–63. doi:10.1891/1939-7054.1.2.51

Root-Bernstein, R. S., Bernstein, M., & Garnier, H. (1993). Identification of Scientists Making Long-Term High-Impact Contributions, with Notes on Their Methods of Working. *Creativity Research Journal*, *6*(4), 329–343. doi:10.1080/10400419309534491

Root-Bernstein, R. S., Bernstein, M. M., & Garnier, H. (1995). Correlations between Avocations, Scientific Style, Work Habits, and Professional Impact of Scientists. *Creativity Research Journal*, *8*(2), 115–137. doi:10.120715326934crj0802_2

Root-Bernstein, R. S., & Root-Bernstein, M. M. (2004). Artistic Scientists and Scientific Artists: The Link between Polymathy and Creativity. In R. J. Sternberg, E. L. Grigorenko, & J. L. Singer (Eds.), *Creativity: From Potential to Realization* (pp. 127–151). Washington, DC: American Psychological Association. doi:10.1037/10692-008

Schwab, K. (2017). *The fourth industrial revolution*. London, UK: Portfolio Penguin.

Schwab, K., Davis, N., & Nadella, S. (2018). *Shaping the Future of the Fourth Industrial Revolution*. New York, NY: Currency.

Seagoe, M. (1975). *Terman and the Gifted.* Kaufmann.

Snow, C. P. (1964). *The Two Cultures: and A Second Look*. London: Cambridge University Press.

Statista. (n.d.). *Number of people who practiced photography within the last 12 months in the United States from spring 2008 to spring 2017 (in millions)*. Retrieved October 30, 2017 from https://www.statista.com/statistics/227424/number-of-photographers-usa/

Stüer, C., Hüsig, S., & Biala, S. (2010). Integrating Art as a Trans-Boundary Element in a Radical Innovation Framework. *R & D Management*, *40*(1), 10–18. doi:10.1111/j.1467-9310.2009.00581.x

Chapter 5
Cognitive Skills Development at Higher Educational Level in the Fourth Industrial Revolution:
A Case for Creativity

Ziska Fields
https://orcid.org/0000-0001-5353-1807
University of Johannesburg, South Africa

ABSTRACT

To compete in the workplace of the Fourth Industrial Revolution, cognitive skills development is critical. The traditional education system is not geared to prepare students for the demands of the future workplace and the disruptions of the Fourth Industrial Revolution and beyond. The objective of this chapter is to explore the development of cognitive skills in higher education with a specific focus on creativity. The chapter explains that higher education institutions need to place greater emphasis on developing cognitive skills and different types of intelligences to meet the demands of the future workplace. Fostering creativity is particularly important in this regard. The chapter presents two ways of assessing creativity and three techniques to develop this key skill in students. The author used qualitatively summarized evidence on the topic using informal and subjective methods to collect and interpret studies and secondary data.

DOI: 10.4018/978-1-5225-9188-7.ch005

INTRODUCTION

Suri (2018, p. 1) believes that *"we are on the cusp of not just a technological revolution, but a productivity revolution. It will bring benefits for people everywhere, make our planet more sustainable, and provide new opportunities for businesses of all kinds"*. To compete in the Fourth Industrial Revolution, cognitive skills development is critical to enable people to deal with the constantly changing and complex digital environment caused by disruptive technologies and sophisticated machine-intelligence (Kaldero, 2019). Business managers are expected to navigate organizations through this unknown territory, develop inventors and problem solvers and ensure that organizations remain flexible, profitable and sustainable. The education system plays a key role in preparing business managers for this difficult task.

In most countries, the traditional education system is not geared to prepare students for the challenges and disruptions of the Fourth Industrial Revolution and beyond. Traditional colleges and universities, for example, have has no serious competition until disruptive technologies created alternative business models for these institutions (Christensen & Eyring, 2011). In addition to this new threat, the World Economic Forum, cited in Soffel (2016), maintains that students need 21st century skills which can be divided into (1) functional literacies (referring to how students apply core skills to everyday tasks); (2) competencies (referring to how students approach complex challenges, and specifically, their cognitive skills); and (3) character qualities (referring to students' approach to their changing environment). Traditional fields of study in silos do not provide the kind of new thinking students will need to thrive in the Fourth Industrial Revolution. Higher education institutions are therefore expected to become more innovative and engaging (Christensen & Eyring, 2011) to instill passion and curiosity and to develop higher cognitive skills in their students. Institutions will also need to reskill and upskill managers and employees, as well as creating new skills, to enable organizations to leverage technology and improve customer service, profitability and competitiveness.

Higher education plays a crucial role in the development of business people, and especially business managers. Business schools focus on preparing future (next-generation) business leaders who can deal with complex societal challenges (Muff, 2013). There has, however, been a shift in expectations, with higher education institutions and business schools placing greater emphasis on the development of students' cognitive skills and intelligence to prepare them for the Fourth Industrial Revolution and beyond. Graduates who become managers or employees now need to be imaginative, creative and responsible to thrive in the future workplace.

The objective of this chapter is to explore the development of cognitive skills at higher educational level with a specific focus on creativity as a cognitive skill. To achieve this objective, the following secondary objectives were set: (1) to motivate why higher education needs to change by focusing on the development of cognitive skills and intelligence; (2) to discuss the importance of creativity development, specifically at higher educational level; (3) to identify ways of assessing creativity; and (4) to recommend techniques that can be used to develop creativity in the Fourth Industrial Revolution. To achieve these objectives, the author qualitatively summarized evidence on the topic using informal and subjective methods to collect and interpret studies and secondary data. The aim was to use more recent sources for the discussions and recommendations.

In this chapter, the background explains how and why higher education institutions need to change. This is followed by a discussion of the importance of cognitive skills development to meet the demands of the future workplace. The focus then moves to one cognitive skill in particular, creativity, and how this key skill can be developed. Solutions are then proposed to the challenges identified in the chapter and practical recommendations are made to assist higher educational institutions to implement creativity in all their degree programmes.

BACKGROUND

MacGregor (2013, p. 1) reports in the University World News that according to Barber, Donelly and Risvi, "the *next 50 years could see a golden age for higher education, but only if all the players in the system, from students to governments, seize the initiative and act ambitiously. If not, an avalanche of change will sweep the system away"*. Thus, change and innovation in higher education are no longer a 'nice to have', but rather a critical 'must' as the system needs to move away from its traditional role in society. The role of higher education in the Fourth Industrial Revolution will be vital in ensuring that the current and future workforce is reskilled and upskilled to deal with the complexity and demands of this era and beyond.

Higher education in the Fourth Industrial Revolution is *"a complex, dialectical and exciting opportunity that can potentially transform society for the better"* (Xing & Marwala, 2017, p. 10). This gives knowledge institutions an important role in preparing people for the future. Xing and Marwala (2017) further explain that the fundamental functions of a higher education institution remain the same whatever the era. The goal of higher education is to ensure the quality and relevance of learning via teaching to enable students to get the latest knowledge through exploratory research and to sustain the development of societies.

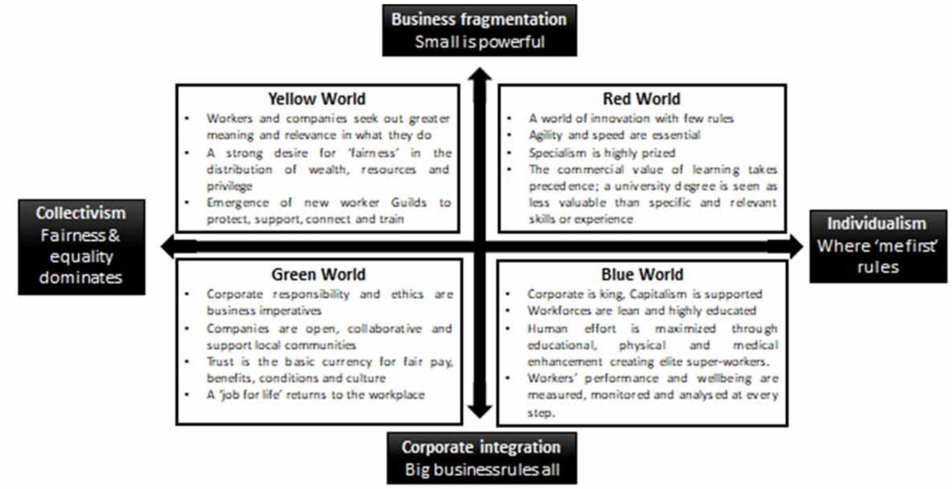
Challenges presently faced by higher education institutions include the slow pace at which higher education is adopting disruptive technology, artificial intelligence (AI) and cyber-physical systems (CPS) in their degree programmes and curricula. For example, the approval and accreditation of new modules and programmes are a long and slow process in South African universities. Approval and accreditation need to be speeded up by streamlining processes, eliminating unnecessary bureaucracy and ensuring that all accreditation requirements are adhered to. New developments in education are also causing challenges in teaching, for example, the access and use of Wearables-Assisted Teaching technologies, competition due to the massive open online courses (MOOCs), the cultivation of innovative talent in developing or underdeveloped countries where skills and knowledge are lacking, the lack of understanding and use of generalized blended learning (a mixed e-learning and face-to-face learning methodology), and negative mindsets against new technologies and novel teaching methods (Xing & Marwala, 2017).

Higher education institutions, governments and industries / businesses need to work together to ensure that higher education meets the demands of the Fourth Industrial Revolution and beyond. The Triple Helix Framework encourages collaboration and the establishment of strategic partnerships to accelerate innovation processes. South Africa, as a developing country, needs a 'fresh triple helix approach' to address the skills gaps and demands according to De Villiers, Duke and Jansen van Nieuwenhuizen (2017). The main goal of the Triple Helix Framework should be to ensure that higher education institutions, governments and industries / businesses reap the benefits of the Fourth Industrial Revolution. This starts with teaching people to realize the significance of technological advancement. In preparing people for their careers, higher education institutions should be involved in enabling human resources to overcome the challenges of the Fourth Industrial Revolution which is powered by artificial intelligence. The future workplace will also be less task-centered and more human-centered, with a convergence of man and machine (Xing & Marwala, 2017).

Higher education institutions, governments and industries / businesses also need to work together to understand and prepare for PwC's imagined 'four worlds of work' in 2030 to ensure that future job skills and leadership capacities are developed in line with these worlds (PwC, 2018). The four worlds of work, summarized in Figure 1 below, imagine different scenarios of how companies will manage people and how people will manage their work and careers in the future. By collaborating, higher education institutions, governments and industries / businesses can avoid or overcome the lack of essential skills – now and in the future. The lack of essential skills is a threat to business growth, innovation, workforce costs, quality standards and customer experience as well as key strategic initiatives which are delayed or cancelled (PwC, 2019). There are also significant social implications for a nation's Gross Domestic Product (GDP), tax revenue, trade, economic development and quality of life (PwC, 2018).

This section has highlighted the significance of higher education, the challenges faced by higher education institutions and the importance of collaboration in the preparation of the future. The next section explores the acquisition of future work

Figure 1. Four worlds of work in 2030
Source: Adapted from PwC (2018)



skills through higher education to obtain the necessary knowledge, skills and intelligence for the future world of work.

COGNITIVE SKILLS NEEDED FOR FUTURE JOBS

New information is generated in less time than ever before and is very easy to access using various technologies. This has a huge impact on teaching, learning and higher education institutions. Göke (2018) asserts that *"a modern degree might last you just five years before it's completely irrelevant"*. Nuez (2018, p. 1) adds that graduates *"probably need to devote at least five hours a week to learning just to keep up with their current field — ideally more if you want to get ahead"*. Neuz (2018) further states that being an expert (also in reference to the 10,000-hour rule popularized by Malcolm Gladwell) will be a disadvantage by 2020 due to the impact of the Fourth Industrial Revolution and the skills needed to manage complexity. In the future, diversity of knowledge and skills will be more important than being an expert in a specific area.

Technology is evolving at an unprecedented rate and businesses are eager to employ graduates with diverse knowledge of management studies, inter-disciplinary approaches to decision-making, the ability to solve complex problems and use a range of cognitive skills. Xing and Marwala (2017, p. 1) add that the skills that are needed now are *"critical skills, people management, emotional intelligence,* *judgement, negotiation, cognitive flexibility, as well as knowledge production and management"*. Therefore, it is the responsibility of higher education institutions to prepare both students and academics for what might be required in the unknown future.

In January 2016, the World Economic Forum issued their Future of Jobs report and ranked the ten key skills for 2020 as: (1) Complex problem-solving; (2) Critical thinking; (3) Creativity; (4) People management; (5) Coordinating with others; (6) Emotional intelligence; (7) Judgment and decision-making; (8) Service orientation; (9) Negotiation; and (10) Cognitive flexibility (Gray, 2016). By 2020, creativity will be one of the top three job skills most in demand (Jezard, 2018) hence this chapter focuses on creativity specifically. The demand for higher cognitive skills such as creativity, critical thinking and decision-making will rise even further by 2030 (Jezard, 2018).

Higher education institutions need to develop these key skills in all students to ensure the employability of their graduates. To enable institutions to educate not only the youth but also government and the business community, new teaching and learning methodologies and strategies need to be identified. These must be integrated with technology and should foster lifelong learning. However, Harari (2018) as cited in Göke (2018, p. 5) encourages educators not to simply give students more information, but rather to focus their teaching strategies on students' abilities *"to make sense of information, to tell the difference between what is important and what is unimportant, and above all, to combine many bits of information into a broad picture of the world"*. Students should be taught to accept multiple viewpoints all at once and then integrate them into a holistic picture that makes sense (Göke, 2018). This is referred to as '*integrative complexity'* according to the author, and requires students to become *'fluid creatures of intelligences'*. This means that students need to be willing to change their perspectives by having an open mind. It is important to teach students how to keep up with the world and changing workplace and to critically review and interpret information. Christensen, Horn and Johnson (2008) refer to this form of teaching as the "disrupting class" where the conventional understanding of intelligence is challenges and lecturers have the freedom to reevaluate and reinvigorate their current programmes.

In 2050, graduates will have to be able to reinvent themselves over and over again and should be able to fully use neuroplasticity and the disruption of education is required continuously. Neuroscience News (2019, p. 1) states that the human brain is *"plastic"* and able to adapt and rewire itself. That is why cognitive skills are so important in education to ensure that graduates can adapt to complexity. The question, however, is 'What are cognitive skills really and how can these be developed for the Fourth Industrial Revolution and beyond?'

Cognitive Skills Development in Higher Education

Cognition is defined as *"the act or process of knowing"* (Edublox Online Tutor, 2019, p. 1). Cognitive skills are interdisciplinary, higher-order thinking skills (Science of Summit, 2019). These skills can be taught and are used to grasp, retain or use information to think, read, learn, remember, reason and pay attention (LearningRx, 2019). Each cognitive skill plays an important part in processing and interpreting data, developing arguments, creating and presenting new ideas and solving problems. The brain can be trained to develop these skills through specific brain training techniques and the use of neuroplasticity. Cognitive development is *"the process of acquiring advanced thinking and problem-solving skills from infancy through adulthood"* and *"is the process by which each of us becomes an intelligent person, acquiring intelligence and increasingly advanced thought"* (Boss, 2015, p. 7).

At a basic level, the building blocks of cognition are represented by nine cognitive skills, as shown in Table 1 below (LearningRx, 2019). Cognitive exercises and brain training techniques can address any weaknesses and improve these cognitive skills.

The Science of Summit (2019) identified 36 cognitive skills that fall into seven domains (as indicated in Table 2 below). These have been validated by the Stanford Center of Assessment, Learning and Equity (SCALE). Students need to develop these cognitive skills in every subject and in every grade.

Andreas Schliecher of the Organisation for Economic Co-operation and Development (OECD) Education Directorate, at the Science of Summit (2019, p. 25), states that *"education today is much more about ways of thinking which involve creative and critical approaches to problem-solving and decision-making"*. Cognitive skills become more complex as brain training increases and even more so in higher education. This is because it is expected that graduates apply knowledge to novel situations. Boss (2015) explains that cognitive development, if applied to higher education, consists of three stages – dualism, relativism and commitment. These three stages are indicated in Table 3 below.

Higher education allows students to acquire better critical thinking, to take responsibility for their interactions with the people and the world around them, to open them up to challenges and to be more accepting of ambiguity (Boss, 2015). Higher education institutions should focus on teaching critical thinking, communication, collaboration and creativity. This is because critical thinking and creativity in particular will be in high demand in the next two to three decades (Jezard, 2018). This view is supported by the educational researcher David Perkins (2014) of the Science of Summit (2019, p. 27) who stresses that *"leadership, entrepreneurship and related skills are dispositions that speak strongly to living and thriving in our era"*.

The ability to think critically and to make effective decisions are shaped by a person's stage of cognitive development, having good analytical skills, communicating

Table 1. The nine building blocks of cognition

Cognitive skill	What it does?	Problems if skill is weak
Attention/sustained	Enables a person to stay focused on a task for a sustained period of time.	Unfinished projects, jumping from task to task.
Attention/selective	Enables a person to stay focused on a task despite distractions.	Easily distracted.
Attention/divided	Enables a person to remember information while doing two things at once.	Difficulty in multi-tasking, frequent mistakes.
Memory/long-term	Enables a person to recall information stored in the past.	Forgetting names, doing poorly on tests, forgetting things one used to know.
Memory/working (short-term)	Enables a person to hang on to information while in the process of using it.	Having to read directions again in the middle of a project, difficulty following multi-step directions, forgetting what was just said in a conversation.
Logic and reasoning	Enables a person to reason, form ideas and solve problems.	Frequently asking, "What do I do next?" or saying, "I don't get this," struggling with maths, feeling stuck or overwhelmed.
Auditory processing	Enables a person to analyze, blend, and segment sounds.	Struggling with learning to read, reading fluency or reading comprehension.
Visual processing	Enables a person to think in visual images.	Difficulties understanding what one has just read, remembering what one read, following directions, reading maps, doing word math problems.
Processing speed	Enables a person to perform tasks quickly and accurately.	Most tasks are more difficult. Taking a long time to complete tasks for school or work, frequently being the last one in a group to finish something.

Source: LearningRx (2019)

effectively, having sound research and inquiry skills and being open-minded, flexible, mindful, curious and being able to solve problems creatively (Boss, 2015). Cognitive development in higher education is therefore the simultaneous development of various cognitive skills. This is because these skills cannot be used in isolation, but should be applied as a whole-brain approach. The development of various cognitive skills simultaneously is challenging in higher education, however, the greater a person's cognitive development, the greater their ability to apply a whole-brain approach to make decisions, solve problems and lead people.

Table 2. Seven domains and 32 cognitive skills

Domain	Cognitive skills
1. Using Sources	• Selecting relevant sources • Contextualizing sources • Synthesizing multiple sources
2. Products and Presentations	• Style and language (tone, academic language, syntax) • Oral presentation • Multimedia in written production • Multimedia in oral presentation • Conventions • Precision
3. Analysis and Synthesis	• Identifying patterns and relationships • Comparing and contrasting • Modeling • Interpreting data and information • Making connections and inferences • Critiquing the reasoning of others • Justifying and constructing an explanation
4. Inquiry	• Asking questions • Hypothesizing • Designing processes and procedures
5. Speaking and Listening	• Discussion and contribution • Preparation • Norms and active listening
6. Textual Analysis	• Theme or central idea • Point of view or purpose • Development • Structure • Word choice
7. Composing and Writing	• Argumentative claim • Informational or explanatory thesis • Narrative • Counterclaims • Selection of evidence • Explanation of evidence • Integration of evidence • Organization (transitions, cohesion, structure)

Source: The Science of Summit (2019)

The building blocks of skills and Sternberg's Triarchic Theory of Intelligence (one of the most comprehensive and compelling theories of intelligence developed and tested over the past 30 years, as cited in Hughes, Ginnette and Curphy, 2015) can be used in higher education to develop those skills which are easier to change through higher education. These skills include knowledge (also seen as practical intelligence), experience (also seen as practical intelligence) and competencies / skills / behaviours (Hughes *et al.,* 2015, p. 208). The building blocks of skills that are difficult to change (but not impossible in higher education) are intelligence,

Table 3. Cognitive development in higher education

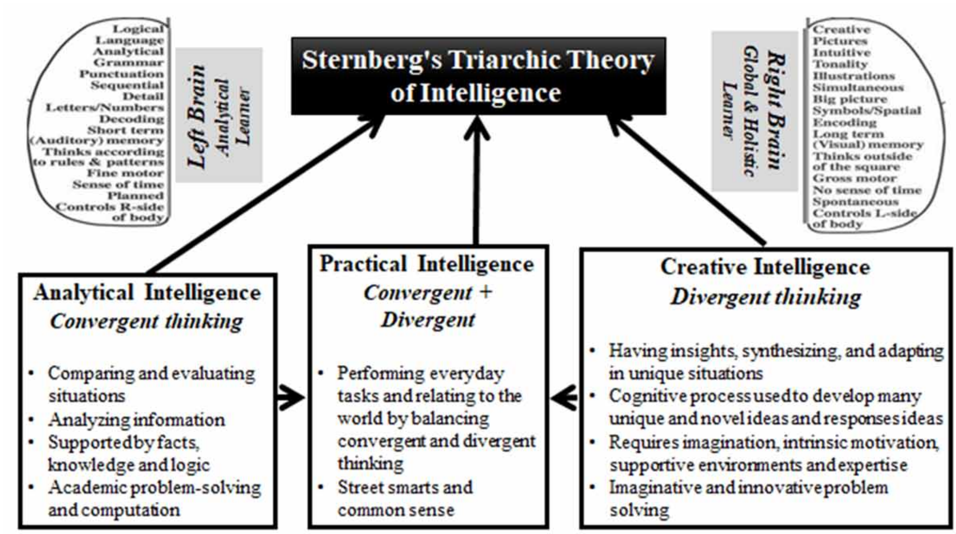
<table>
<tr><th>Stage 1:
Dualism</th><td rowspan="5">Transition to Stage 2: There are some uncertainties and different opinions that are mostly temporary</td><th>Stage 2:
Relativism</th><td rowspan="5">Transition to Stage 3: This happens when students learn about their limits, contradictions in their thinking and encounter role models at a higher stage of cognitive development.</td><th>Stage 3:
Commitment</th></tr>
<tr><td>Who?
Younger students.</td><td>Who?
Mostly senior students doing their first degrees.</td><td>Who?
Mature students.</td></tr>
<tr><td>What?
Dualism is to see things as either right or wrong.</td><td>What?
All truth is seen as a matter of opinion and there are no right or wrong answers.</td><td>What?
Not all thinking is equally valid.</td></tr>
<tr><td>How?
Students seek evidence that supports their views and dismiss opposing views.</td><td>How?
Students believe that stating their opinion is the proper mode of expression and they believe that judging others’ opinions is disrespectful.</td><td>How?
When students experience uncertainty, they are now able to make decisions, commit to a specific position based on reasoning and the evidence available. They realize that authorities can make mistakes.</td></tr>
<tr><td>Making decisions
Authoritative figures provide the answers and direction in conflicting and controversial issues.</td><td>Making decisions
Students expect their professors to support their opinions.</td><td>Making decisions
Students are independent and flexible thinkers who are open to opposing views and willing to change their position based on new evidence. They know that uncertainty and ambiguity is unavoidable.</td></tr>
</table>

Source: Adapted from Boss (2015)

personality traits and preferences, values, interests and motives. Figure 2 explains the three types of intelligence identified by Sternberg. The Triarchic Theory of Intelligence is useful in the Fourth Industrial Revolution and higher education as it contains important implications for leadership. It explores what happens when leaders need to solve complex mental and even ‘wicked’ problems by comparing and evaluating situations, combining and synthesizing information, generating many novel and new ideas, using imaginative and innovative problem-solving and practically applying their convergent and divergent thinking.

This chapter specifically focuses on creativity as a cognitive skill and intelligence. Creative intelligence (CI) refers to the ability to produce both novel and useful work (Hughes *et al.,* 2015). This means that any creative idea should indicate newness

Figure 2. Sternberg's Triarchic Theory of Intelligences
Source: *Adapted from Graham (2013) and Hughes et al. (2015)*



but should also have the potential to be realistically implemented or have some type of practical payoff. It is evident that creativity has a relationship with analytical intelligence and practical intelligence. This relationship, however, is imperfect and creativity seems to still be linked to specific fields and sub-fields (Hughes *et al.*, 2015). The next section explores creativity as a key cognitive skill and intelligence.

CREATIVITY: A KEY SKILL IN THE FOURTH INDUSTRIAL REVOLUTION

Creativity is one of the most important skills to have in the Fourth Industrial Revolution (Gray, 2016; Jezard, 2018). Boss (2015, p. 12) concurs, stating that *"creative thinking is a much sought-after skill in the business world"*. Creativity is thus becoming more and more important for businesses, leaders and workers as it refers to the "*quality, appropriateness, practicality and usefulness"* of original ideas (Henry, 1991, p. 3). Creativity can generate answers to complex problems and can therefore help businesses and leaders to prosper in the Fourth Industrial Revolution and beyond.

Creativity is often seen as something mystical that leads to *"images of wonderful insights, imaginative efforts, illumination and intuitions from nowhere"* (Henry, 1991, p. 3). It is seen as a skill that one is born with, rather than a skill that can be acquired. However, as more research has been conducted, people's understanding of creativity has changed. Creativity is indeed teachable as it is a "*thinking process that requires imagination, insight, invention, innovation, ingenuity, inspiration and illumination"* (Henry, 1991, p. 3). Creativity, which is both a cognitive skill as well as a form of intelligence, refers to *"the ability to solve problems with relevance and novelty"* (Petrone, 2019, p. 1). A general view of creativity is that it involves 'thinking outside the box', thinking differently, from a new perspective or challenging the status quo, breaking the boundaries of an imaginary prison (the box). There is also a view that creativity can only be achieved when a person 'thinks without a box', which makes the person completely free of any limitations and opens up infinite possibilities for innovation.

Creativity, as conceptualised by De Brabandere and Iny (2013), is better-suited to the Fourth Industrial Revolution due to its complexity and multifaceted technological and disruptive nature. The authors contend that business leaders and workers will need to *"juggle multiple theories, models and strategies"* in their mental models or boxes at the same time to interpret what is happening around them, utilize opportunities and solve complex problems (De Brabandere & Iny, 2013, p. 5). Higher education needs to help people to learn to think in these new and updated mental models (boxes), develop new mental models, understand the rules and practices that tie them to their models and identify the kind of box they are using (for example, concepts, stereotypes, judgements, patterns, categories, working hypotheses, ideas, frameworks, paradigms, structures). This view is linked to Sternberg's Triarchic Theory of Intelligence insofar as a person's brain needs models or boxes in which to think; this is the key to being creative in practical ways as it combines convergent and divergent thinking.

Barriers to Creativity

Higher education institutions need to be aware of the possible barriers to creativity that students may experience. Adair (2010) and Whetten and Cameron (2016) identify barriers such as:

- Students may fear failure and if they do not truly understand creativity, they may not be willing to participate fully in creativity development activities and assessments.
- Students have the tendency to focus on the negative aspects of problems and they may try to avoid problems rather than solving them using their creative thinking skills.

- Students at higher education institutions often do not have time to think creatively as they may be overstressed due to academic demands. Creativity requires time to daydream and time for illumination to occur.
- Students have been taught that logic and analytical intelligence are more important in academia and they will utilize their logic first when they encounter a complex problem or situation.
- Students have conscious and unconscious assumptions about creativity.
- Students have the tendency to conform to the rules and limitations of the status quo which can prevent creative thinking.
- Students, like most people, have trouble solving problems creatively. They see creativity as one-dimensional insofar as it is limited to generating new ideas only.
- Students, like most people, develop certain conceptual blocks that inhibit their creativity.

Bragg and Bragg (2005, p. 64) point to a *"creative procrastination zone"* that can act as a barrier to creativity. This "creative procrastination zone" considers timing and analysis – there is always a right time for a specific opportunity (neither too soon nor too late). Knowing the right time requires a special skill and experience which students all too often do not possess. The same applies to analysis where students may be overly reflective and analytical; this can waste time and energy (analysis paralysis). Others may be under-analytical (premature panic) which can also cause problems, as students may be unaware of risks or come up with great ideas that are premature.

Barriers are real and can hamper creative development and creative thinking. Not only should students be made aware of barriers towards creativity, but they should also know what their own individual barriers. They should be taught how to overcome these to fully utilize their creative potential. This is especially important in the Fourth Industrial Revolution.

Creativity Development for the Fourth Industrial Revolution

Creativity enables people to view problems from multiple perspectives, to generate various solutions for each problem, to evaluate these solutions logically and critically and to select the best solution (Boss, 2015). Using one's imagination enables a person to envision possibilities, potential problems and to explore solutions that may not exist as yet because there are no limitations to a person's imagination. Stephen Hawking as cited in De Brabandere and Iny (2013, p. 246) clarifies that *"[t]oday's science fiction is often tomorrow's fact"*. Creativity also requires people to take risks, accept unexpected and unusual outcomes as well as possible failure in their efforts to be creative (De Brabandere & Iny, 2013). Robinson observes that *"[c]reativity is not the opposite of discipline and requires a deep knowledge of facts and a high level of practical skills"* (Newsroom, 2019, p. 4).

Creativity development is not new. In 1956, Louis R. Mobley established the IBM Executive School based on six insights after he realized that IBM executives needed to be taught to think creatively (Turak, 2011). These insights are as follows:

1. The key to creativity and building new mental models is to ask radically different questions in a non-linear way and avoid traditional education methodologies.
2. Creativity is not something a person learns, but rather becomes, as it opens up alternative modes of thinking.
3. Becoming creative is an unlearning rather than a learning process.
4. Being in the presence of other creative people and an unsystematic, unstructured environment with peer-to-peer interaction is the fastest way to become creative.
5. Self-knowledge is critical for creativity; people need to understand where their mental models are coming from and they need to challenge their way of thinking and perceiving the world with courage.
6. People need to be willing to make mistakes, fail and make fools of themselves in the search for creative ideas.

Given these IBM insights, it was already clear in 1956 that traditional educational methodologies were not developing creativity. This is still true today, with increasing calls for the re-imagining of teaching and learning methodologies to ensure that people are adequately prepared for the future. Part of this reimaging of creativity education is to access students' creativity development on an ongoing basis throughout the duration of their studies. The idea is to provide students with individual and specific feedback on how their creativity can be enhanced, using technological tools to develop and test their creativity. Creativity also needs to be applied to every module and field of study offered at a higher education institution.

This section discussed the notion that creativity is one of the most important cognitive skills in the Fourth Industrial Revolution. It is also a teachable skill. The section also explained that although awareness of creativity is not new, it is becoming a more critical skill to acquire in the present day. There are different ways of fostering creativity at higher educational level; the next section shares some practical ideas to develop creativity.

SOLUTIONS AND RECOMMENDATIONS

A good recommendation was made by Penprase (2018) that any educational plan for the Fourth Industrial Revolution should consider a hybrid online and in-person instruction, integration of global videoconferencing, asynchronous educational resources, blended instruction, optimization of flipped and online courses, and an interdisciplinary and global curriculum.

There are numerous ways to develop cognitive skills at higher educational level. The aim of this section is not to provide academic recommendations that should be followed in all teaching and learning activities, curriculum development or specific pedagogies. Instead, the aim is to highlight areas that can be considered in cognitive skills development by specifically focusing on creativity. Thus, this section presents two ways of assessing creativity throughout an undergraduate degree and three techniques for developing creativity in the Fourth Industrial Revolution.

Assessing Creativity

Assessing creativity is important in higher education in order to determine the level of creative intelligence and creative thinking skills before, during and after any teaching and learning activity, programme or practical work. These assessments should form part of each student's Portfolio of Creativity Evidence file which should be used to track creativity development for the duration of study. Cropley (2008) states that there are some 255 creativity tests in existence. According to Epstein, Schmidt and Warfel (2008), these include personality tests with creativeness scales, tests that measure the different styles people use to express creativity, tests that measure divergent thinking, tests that measure how suitable various environments are for creative expression and tests that measure creative achievement. Cropley (2012) is, however, concerned that attempts to nurture creativity in higher education are still problematic due to most educators' poor understanding of what is involved, how to best assess creativity over time and the technical shortcomings of most of these assessments. Cropley and Cropley (2016) add that most computer-assisted assessments (CAA) used by higher education institutions fail to assess higher order cognitive skills of students.

This section discusses two assessments of creativity which have been extensively and scientifically tested and validated. These assessments – the Fields Educational Creativity Model (FECM) and the Creative Solutions Diagnosis Scale (CSDS) – are shown in Table 4 below. The FECM and CSDS use specific assessment focus areas which can be used to guide students and lecturers on what they need to do to promote creativity in the classroom. Each type of assessment tool is identified and recommendations are made on how the assessment and results can be used to foster creativity.

Table 4. Two assessments of creativity: The Fields Educational Creativity model (FECM) and the Creative Solutions Diagnosis Scale (CSDS)

Name of model / instrument	Assessment focus areas	How is creativity assessed?	How can it be used to develop creativity?
The Fields Educational Creativity Model (FECM) created by Fields and Atiku (2015) SPSS and Amos were used to statistically test the validity and reliability of the model to assess creativity.	● Cognitive psychology, motivation, creativity.	● Completing a questionnaire using a five-point Likert scale. ● Assessing students' motivation to challenge the status quo, solve problems, the fluency of their ideas and dimensional thinking.	After determining the level of creativity based on students' cognitive psychology and motivation, higher education institutions can focus on: ● Developing students' external cognitive processes using external aids (for example, visualization, work spaces) and internal cognitive processes, which involve perception, attention, language, memory and thinking. ● Teaching methods and assessment should focus on developing whole-brain thinking and students should be encouraged to challenge the status quo, use dimensional thinking as well as using creative problem-solving and fluency to generate viable and sustainable ideas. ● Progress should be measured to determine individual students' creative development throughout the duration of an educational programme. ● Aligning teaching-learning materials with methods of testing that will promote memory, comprehension, skills for practical work and creativity. ● Creativity boosters for students by investing in teaching environments that enhance creativity, for example, using green lecture venues to activate creative thinking, having a 'creative time out' space to encourage the incubation of ideas as part of the teaching and learning process and stimulating curiosity by using different teaching techniques.

continued on following page

Developing Creativity Using Theoretical Knowledge Acquisition and Techniques

Theoretical knowledge can be conveyed using methods such as lectures, seminars, books, audiobooks, eBooks, journal articles, videos, mobile device apps, online training systems and assignments. Analytical and creative intelligence is stimulated when knowledge is acquired and applied to a specific case study, class discussion or group assignment.

Table 4. Continued

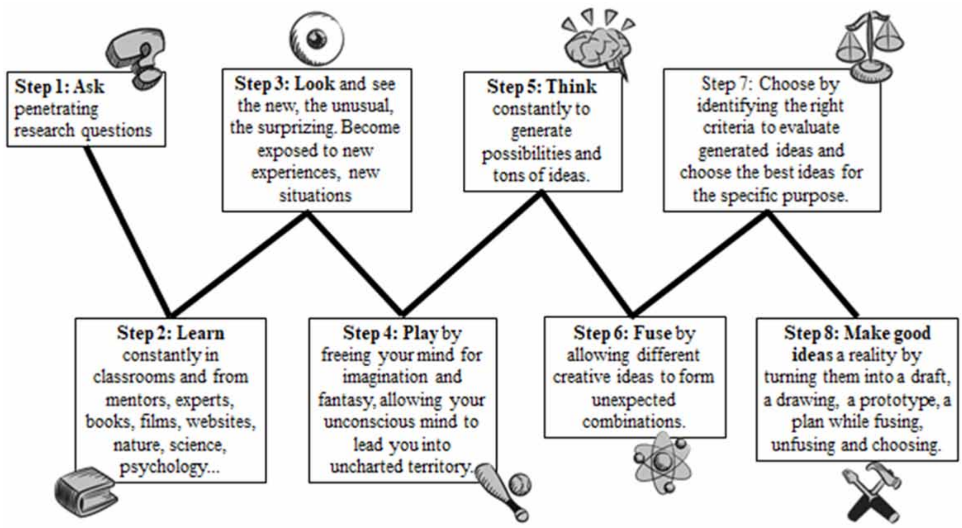
Name of model / instrument	Assessment focus areas	How is creativity assessed?	How can it be used to develop creativity?
Creative Solutions Diagnosis Scale (CSDS) created by Cropley and Cropley (2016) The app underwent developmental and operational testing to ensure that the tool was robust and met the needs of teachers and students	• Relevance and effectiveness (the output is fit for purpose). • Problematization (the output helps to define the problem/ task at hand). • Propulsion (the output sheds new light on the problem/task). • Elegance (the output is well-executed). • Genesis (the output changes how the problem/task is understood).	• A mobile device app using a five-point Likert scale. • Assesses the relevance, effectiveness, novelty, elegance and generative quality of products. • The focus is mainly on how practical, novel and useful the ideas are.	After determining the level of creativity used by students to develop creative products (essays, compositions, artefacts), higher education institutions can use the results to teach lecturers and students. Lecturers can be helped to understand: • What and how to teach students to improve the creative quality of their creative products, • How to communicate expectations of creativity outcomes to students, parents and stakeholders effectively, and • That assessing a creative product involves a whole-brain approach and not a linear, one-right-answer mindset. Concrete and differentiated feedback can be provided to students indicating: • The overall creativity achieved for their creative products (a summative assessment) and how they can improve this overall creativity. • The strengths and extent of their creativity by exploring how their creative products defined and solved specific problems. • In very concrete terms, the specific characteristics that contributed (or failed to contribute) to the product's creativity (a formative assessment) which allows the student to take specific action to address shortcomings.

***Source**: Author (2019) adapted from Fields and Atiku (2015) and Cropley and Cropley (2016)*Students should be made aware of the mistakes they made in their creative assessments. Detailed comments should be provided on mistakes as well as suggestions on how to avoid these in the future. Sawyer (2013) points to the following common mistakes: (1) thinking that creativity is only needed occasionally and (2) hoping that there is one great idea out there. Lecturers need to encourage students to put in an effort to grow their creativity and to persist in order to make creativity a habit. Once the current level of students' creativity is assessed, theoretical knowledge on creativity should be imparted and knowledge gaps identified. Various techniques and mobile phone applications are available to help students understand creativity and become more creative.

Acquiring knowledge means that students should become familiar with the most important findings, tendencies, models and theories of creativity. Knowledge links should then be made to their current study area. Creativity requires a broad and holistic view of theory. Acquiring knowledge implies the gaining of insight (creative insight), the ability to justify and evaluate claims based on analysis, systematizing and learning (Rossouw, 2014).

Dr. Michael Bloomfield created the Kleytro™ creativity training system that can be used to enhance students' understanding and knowledge of creativity. Kleytro™

Figure 3. Eight Zig Zag Steps
Source: Author (2019) adapted from Sawyer (2013, pp. 6-7)



sees creativity as a language with learnable grammar; the training system consists of structured exercises to help students internalise the grammar of creativity (Bloomfield, 2018). First-year students should be introduced to the Kleytro™ creativity training system to help them unlock their creativity and train their brains. This training system improves students' creative intelligence as it enhances their capacity to be imaginative and inventive in any field of study.

Theoretical knowledge about creativity and practical application can be developed using mobile phone apps. Some of these apps available from the Play Store are:

- *Creative Everywhere App*: The exercises on this app use creative thinking skills.
- *Developing Creativity App*: This app contains a detailed guide about creativity and explains various methods that can be used to develop creative thinking. For example, computer-aided creativity, artificial intelligence models, software visualization tools, spatial information systems and much more. This app focuses on technological developments that are useful in teaching creativity for the Fourth Industrial Revolution.
- *Creativity Pro app*: Creativity techniques are used to generate new ideas. These techniques include the six thinking hats, Exquisite Corpse, SCAMPER and combinations of various techniques.

- *Critical and Creative Thinking App*: This app explores the fundamentals of critical and creative thinking.
- *75 Tools for Creative Thinking App:* This is a card set that stimulates creativity thinking in various stages of any process or situation where new ideas are needed.
- *Creativity - Become Creative App:* This app explains, for example, how people can become creative, brainstorming and creative learning.

Various creativity techniques and tools are available to develop creativity. Three techniques are discussed below, namely, Sawyer's eight-step Zig Zag technique to greater creativity, De Brabandere and Iny's five-step approach to thinking in new boxes and Vandervelde's five creativity techniques that turn constraints into creative ideas.

Technique 1: *Sawyer's eight-step Zig Zag technique to greater creativity (2013)*

According to Sawyer (2013), there are eight steps (see Figure 3) involved in being creative which can help anyone to be and think more creatively. He adds that creativity is not a mystery as there are proven techniques for enhancing creativity in anyone. This is welcome news for students who think that they are not creative, who do not know when they are creative or who think that they are just a little creative. Sawyer (2013) maintains that these mindsets can change and believes that each student should answer the question 'Are you creative?' with a convincing and loud 'YES'.

Sawyer (2013, pp. 27-214) identifies specific activities and exercises that can be used in every step. For example:

- Step 1 focuses on finding the 'bug' (problem) by using a fishbone digram or mind map.
- Step 2 asks students to apply what they know to new situations, recruit a mentor and customize knowledge.
- Step 3 encourages students to look for new patterns, switch perspectives, keep an idea log and look for bad ideas.
- Step 4 can be used to encourage students to imagine parallel worlds, to explore the future, to start a hobby and do something for the first time.
- Step 5 is used to encourage action from students by listing attributes of work, for example, and starting 'idea time' (a time when an individual student thinks at their best) and 'idea quota' (for example, to generate at least ten creative ideas per day).

- Step 6 challenges students to combine various concepts to create something new, to mimic nature using the power of biomimicry and to talk to someone different every day.
- Step 7 requires students to sort their ideas by coloring their choices into four groups (not-so-original but highly feasible, very original but not really feasible, very original and highly feasible, and not-so-original and not feasible).
- Step 8 requires students to make their ideas valuable practically. This can be done by using drawings, photos, making a collage, writing a song and singing it or acting the idea out.

Sawyer (2013) created Zig Zag Creativity Cards which can be a useful tool in higher education (as shown in Figure 4 below).

Technique 2: *De Brabandere and Iny's five-step approach to thinking in new boxes (2013)*

The five steps of De Brabandere and Iny's approach are discussed below.

Figure 4. Zig Zag Creativity Cards
Source*: Trainer Warehouse (2019)*

Step 1: Doubt everything

Students are asked to doubt everything they know and question what they think they know. Students are further made aware of the fact that each person is pre-wired with preconceiving ideas, prejudices and mental models to explain the world around them. Three essential tasks are required to help students foster doubt and open their minds (De Brabandere & Iny, 2013, pp. 41-42). The first task is to create a climate of doubt by sensitizing students to their cognitive biases. The second task is to make students aware of their current mental boxes and to challenge these. The students are required to explore these boxes critically and come up with ways to revise, enhance or replace the models. The third task is practical in nature whereby each student needs to frame a set of boxes to investigate further and then to determine if these sets of boxes will help them to achieve the outcomes that need to be delivered. This step stretches students' minds by positioning them to think about the future in an open-ended way.

Step 2: Probe the possible

Students are asked to investigate the world in front of them with a specific focus on how the Fourth Industrial Revolution will affect businesses, societies and economies in the future. Megatrends and global waves of change are investigated and students are encouraged to ask the right questions rather than determining the right answers.

Students are then required to use predictive and prospective thinking to probe what is possible (De Brabandere & Iny, 2013). Prospective thinking is used to anticipate long-term and disruptive changes and to prepare for these before they happen. This type of thinking is used when the level of uncertainty is very high. Scenarios using qualitative approaches are normally used. Prospective thinking can help to foresee events that are likely to occur where the level of uncertainty is average. Established quantitative models are used as techniques and forecasting is inferred from present and past events.

Step 3: Diverge

This step uses divergent thinking with students required to generate a multitude of ideas, new models, concepts, hypotheses and ways of thinking (De Brabandere & Iny, 2013). Nothing is rejected in this step. There are a variety of divergence exercises to be followed. However, this step cannot take place effectively unless a creative environment is fostered in the classroom. Ground rules should be established in terms of sharing of ideas, allowing everyone to contribute and ensuring that everyone respects the ideas and individuals during the process. Participants should be encouraged to be open-minded.

De Brabandere and Iny (2013, pp. 131-149) recommend various divergent exercises. A few examples are indicated below:

- Describe your company without using five key words (the key words for a bank, for example, would be something like money, bank, checking, savings, financial).
- Break constraints and shatter some existing mental models and deliberate to see what new and interesting possibilities emerge (for example, your goal is to break into the luxury yacht market but you only have navy experience; imagine a situation where a famous billionaire is talking to the media and other famous friends about your new type of yacht – how did this happen? What happened to the constraints?).
- Imagine your company has disappeared and speculate why and how this happened.
- Examine your organization and hypothetically break it up into two mutually exclusive and comprehensive different parts. How can this be done? How would you suggest breaking your organization in two? What would you call these parts?
- How would your life change if you woke up and discovered you were the President of South Africa? Participants should immerse themselves in a distinct point of view to enable them to adopt a totally different perspective.
- Consider what steps you would take as the Australian federal government if over the next ten years global warming made the entire Southern Hemisphere entirely uninhabitable.

Step 4: Converge

Students are now required to apply their logical intelligence. Ideas generated during Step 3 are now critically evaluated using convergent thinking. The key objective of Step 4 is to enable students to select the right new box(es) to focus their vision. The process fosters a new kind of creative process which is practical and sustainable. An important decision in this step is determining which students should be part of the convergence process and who should not. It is ok to use the same group as in Step 3, but students may select another group due to their deeper knowledge and ability to make more informed judgments.

De Brabandere and Iny (2013, pp. 167-173) recommend the following focus areas for students to consider during Step 4:

- Practical constraints should be identified such as caps on internal and external resources or practices and activities that are restricted by existing agreements, policies or industry standards.
- Alignment should be ensured and include strategic outlook, competence and values.
- Feasibility should be tested by considering resources, financial returns, marketing requirements, geographical requirements, regulatory and legal requirements, technological developments as well as research and information sources.
- The impact of the idea or decision should be evaluated taking into account the following: reputation / brand, competitive advantage and differentiation, externalities, operational efficiencies, risk / consequences of failure.
- Prioritizing, voting and making recommendations is critical after the impact is established.
- Multiple rounds of divergence and convergence are required.

Step 5: Reevaluate relentlessly

Students need to understand that a good idea or box will not be good forever. Constant reevaluation, modification and innovation is important, and even more so in the Fourth Industrial Revolution. For most businesses, replacing something at the perfect time is a huge challenge. It is therefore important to constantly look at what is happening around the business and identify future trends. When it comes to boxes, knowing when it is time to replace an existing box with a new one requires finely-tuned mindsets.

De Brabandere and Iny (2013) explain that a 'Caramba' moment takes place when there is a strong indication that a current box must be reevaluated due to the fact that it is inconsistent with existing approaches, beliefs, paradigms or other boxes. A possible exercise is to ask students to consider the impact of technological disruption of the Fourth Industrial Revolution on them personally. This can be done by considering the Blue world of work in Figure 2 above. Workers will be required to be the best, so how will the use of smart drugs and mental upgrades fit into their current mental models.

Students should also be able to identify weak signals and note that people and organizations have unique subjective mental frameworks, where some can see signals clearly and others do not. Some common weak signals are a changing value proposition, entry of new suppliers and competitors, a new breakthrough in technology, unfulfilled business and other potential opportunities, broad disruptive events and premonitions. Students should be encouraged to keep their eyes open, to keep on doubting and evolving and to think strategically in the Fourth Industrial Revolution.

Applying these five steps in higher education teaching and learning activities will enable students to prepare for the future workplace and the four worlds of work as discussed earlier. Their cognitive skills and their analytical, creative and practical intelligence will be developed. Students will be able to think creatively using existing and especially newly developed mental models through higher education which will make them employable, entrepreneurial and prepared for whatever the future holds.

Students will need to stay on top of their own mental models and will be encouraged to question their mental models by determining if they need to discard old mental models and develop new mental models or keep their old mental models and question the need and usefulness of developing a new mental model. Students need to take thoughtful risks and learn from examined failure. The aim is also to make students aware if they are overly attached to their old mental models as this will trigger the need for the students to start a new process of 'doubting'.

Technique 3: *Vandervelde's five creativity techniques that turn constraints into creative ideas (2018)*

Vandervelde (2018) asserts that a person should be able to drive creativity everywhere using their Constraint Suite, as shown in Table 5 below. This Suite consists of five creativity techniques. Each technique focuses on something different and is very practical. These techniques can be used with great success in higher education teaching and learning activities and assessments.

These three techniques are easy to use and can create a lot of fun and creativity in higher education. If creativity is improved through such exercises and other developmental pedagogies, it will be evident if students see things in new ways due to the new mental models they have created. Student leadership in groups will be evident if leaders use their power constructively to enhance creativity and form diverse problem-solving groups. The students will also start focusing on managing creativity by setting goals, providing adequate resources, reducing time pressures, considering various rewards and recognizing that creativity is evolutionary. In the next section, future research directions are explored.

FUTURE RESEARCH DIRECTIONS

Cognitive skills (like creativity) will become the currency for future job opportunities and business partnerships. People will compete fiercely to obtain these skills and, due to disruptive technologies, possibilities will exist to modify people cognitively and physically. More research is therefore required to determine how this will affect

Table 5. Constraint Suite

Technique name	Focus of the technique	Suite documents needed	How it works
The Frugalizor	Frugal innovation (cheap innovation for the masses)	The Frugalizor poster and the Frugalizor tent cards	Step 1: ● Place students around a table (ideally at least eight students) and give the student post-its. Step 2: ● Each team chooses one or more tent cards to put in front of them on the table. ● The team needs to generate as many ideas a possible within 5-10 minutes related to the mechanism on the tent card/s and write ideas on post-its. Step 3: ● Decide how many rounds of idea generation are needed and when the process will be completed/done. Step 4: ● The team needs to use the ten elements on the Frugalizor: Defeaturing, Multi-purposing, Userizing, Beltizing, Localizing, Ecologizing, Economizing, Robusting, Crowdsourcering, Unlinking, Decosting
Tree of Trade	Thinking in alternatives	Tree of Trade sheet and Tree of Trade poster	Step 1: ● Discuss the central question or problem and write these down; these must be visible at all times to the students. ● Students need to create a list of as many elements as possible that are associated with the central question or problem and stick it on the wall. Step 2: ● Take an element from the list, write it on a post-it and stick it in the circle 'MISSING ESSENTIAL' Step 3: ● Within the group, discuss which need this element fulfils regarding the question or problem and stick it in the circle 'RELATED NEED'. Step 4: ● Select the four most original ideas and stick these on 'ALTERNATIVES A, B, C, D' Step 5: ● Focus on the problem and see which of the 'ALTERNATIVES' can be an actionable idea. Try to find three 'TRANSLATIONS' per alternative and stick it on 'TRANSLATION 1,2,3' Step 6 ● Go back to step 2 and repeat
The Propeller	Analyse constraint(s), dig deeper and use the Propeller to give you a clear overview of the challenge	Propeller sheet and Propeller poster	Step 1: ● Why is it a constraint? What does it withhold? In which way does it restrict what? Dig deeper with each step. Step 2: ● How can we encounter this constraint? How can this issue be solved alternatively? Think creatively. Step 3: ● Build on the solution you came up with and/or try to fine tune it. Make it real and applicable
The Casual Constraint Contest	Teamwork, competition, restrictions	CCC sheet 'What if' constraint cards A six-color die Red, yellow and blue pawns.	Step 1: ● Cut the constraint cards (What If Cards.pdf), shuffle them and put them in the middle of the table, blank side up. ● Cut the sheet with the yellow, red and blue pawn cards (What if Colors. pdf) and let each participant pick one card blindly. ● Ideally, the number of colors should be equally distributed among the participants (that is why a multiple of three participants is needed). ● Cut and assemble the color die (What If Dice.pdf)

continued on following page

Table 5. Continued

Technique name	Focus of the technique	Suite documents needed	How it works
			Step 2: ● Discuss the central question or challenge and ensure that everyone understands. ● Write the question on the heading of a flipchart and keep it visible during the entire process. Step 3: ● Form teams of two participants each. Based on the outcome, teams are formed into: ORANGE - Team(s) of yellow and red; Team(s) of blue and blue GREEN - Team(s) of yellow and blue; Team(s) of red and red PURPLE - Team(s) of blue and red; Team(s) of yellow and yellow YELLOW, RED or BLUE - Team(s) of yellow and yellow; Team(s) of red and red; Team(s) of blue and blue Step 4: ● Each team picks three constraint cards from the stack and checks the 'What if' question that is written on each card. ● Each team gets ten minutes to come up with creative ideas to solve the central question or challenge (written on the flipchart), taking into account each 'What if' question on the constraint cards. Do not combine the three constraints as it will be too difficult or may even be contradictory. Just treat them separately. ● Note that for each separate constraint, the team needs to come up with at least three valuable ideas. If not, they will lose ten points. If the team thinks that they will not be able to think up at least three ideas for one or more of the constraint cards, they can put that card back and replace it with a new one from the pile. In that case, they lose one minute of time per card. So, for instance, if you replace two cards, you get only eight minutes to come up with creative ideas. ● Set the timer to the right number of minutes for each team to start conjuring up ideas. Each idea is written separately on a post-it. Step 5: ● When game time is over for everyone, each team sticks their ideas accompanied by a quick explanation on the flipchart. ● The number of ideas is counted and the points (one per idea) are awarded to the teams. Again: fewer than three ideas per constraint card means ten points. The points are then divided 50/50 among the two team members. ● Now you can start again: new teams are formed and new constraint cards are drawn. So, back to STEP 3. It is best that you decide in advance how many rounds you want to play. Usually, three rounds are recommended. Step 6: ● After the game is played, each participant shows how many points they have collected. The participant with the highest number of points has won. ● The group now decides how many ideas they want to develop into a concept. Ideas can be selected by sticking stickers on the preferred ideas (and the most 'stickered' idea(s) will be developed), or the group can decide to form (small) teams again, with each team picking one idea that they want to work on.

continued on following page

Table 5. Continued

Technique name	Focus of the technique	Suite documents needed	How it works
The River	Problem-solving	River sheet River poster	Step 1: • Make teams of two or more people with a maximum of four teams per session. • Each team rolls the dice. The number they throw correspond with the option they will work on that is mentioned in the printed graph. For example, 1 = swim, 2 = bridge (skills, materials, tools, insights to build one), 3 = block (persuasive and persevering to block river temporarily or for good?), 4 = bypass (time, patience. Lean mind set to walk around the river?), 5 = sail (flexible and adventurous), and 6 = fish (smart and creative mind set to accept the river) Step 2: • The lecturer must separate the teams by placing small tables and chairs along the outside wall of the room. • Start the clock: during the next six minutes, each team will generate ideas according to the received option (the number they rolled with the die). They will write their ideas on post-its they do not share with the group yet. • When the clock stops, each team sticks and presents its ideas to the right of the respective option on the sheet. Step 3: • The group can decide to keep the same teams or to change them. STEP 2 and STEP3 are repeated. If a team or team member gets an option assigned that they already worked on, the team rolls the die again. • According to your number of participants, you can repeat these steps several times. It is important for ALL of the options to be addressed by at least two teams. Step 4: • When you decide to stop the session, select the best ideas on the sheet and start developing these into concepts.

Source: Vandervelde (2018, pp. 179-184). Tools can downloaded from www.whentheboxisthelimit.com

people, what can be done ethically and how people can be accommodated who do not have the highest cognitive skills in society.

Creativity training should be implemented in all schools and educational institutions across the world and the best tools, curricula and techniques should be researched and tested to determine how creativity was developed and to what extent. This means that computer-aided technology, artificial intelligence models, software visualization tools, spatial information systems and other technologies need to be developed through extensive research on cognitive development.

Improving creativity and other cognitive skills requires extensive research on the application of neuroplasticity for children and adults.

More research also needs to be done on universities of the future to assist universities and higher education institutions to adapt more quickly to the requirements of the Fourth Industrial Revolution and beyond. Higher education institutions, like universities, are changing too slowly, and ways should be developed through research to make universities more entrepreneurial, innovative and open to collaboration by breaking down the silos between fields of study.

Techniques, tools, apps and software need to be constantly developed, evaluated, changed, improved and adapted through research.

CONCLUSION

Cognitive skills development in higher education has never been more important. Cognitive skills development needs to start at a young age to prepare people for the high order cognitive skills needed in future. Higher education institutions are required to prepare students for the future workplace. This means that all lecturers must be trained properly and know how to teach and assess cognitive, skills such as imagination and creativity, which should also be included in the teaching philosophies.

This chapter highlighted the development of cognitive skills in higher education with a specific focus on creativity. The chapter motivated why higher education institutions need to focus on developing cognitive skills and different types of intelligence to prepare students for the future world of work in the Fourth Industrial Revolution. Creativity was identified as one of the most important skills both now and in the future. Two ways of assessing creativity were identified and three techniques to foster creativity were described.

REFERENCES

Adair, J. (2010). *Six barriers to creative thinking and innovation*. Retrieved January 5, 2019 from http://www.1000ventures.com/business_guide/crosscuttings/creativity_6barriers_ja.html

Bloomfield, M. [Creative Being]. (2018, October 1). *Can you unlock your creative genius?* [Video file]. Retrieved June 1, 2019 from https://www.youtube.com/watch?v=qbV_c3gyoiw&feature=youtu.be&fbclid=IwAR0EOxQ-P0agFY-NIYfzI5rrAajI5aLKOGB79vPLyuBUdUzLNcEYe4A-ZRs

Boss, J. A. (2015). *THiNK: Critical thinking and logic skills for everyday life* (3rd ed.). New York, NY: McGraw-Hill Education.

Bragg, A., & Bragg, M. (2005). *Developing new business ideas: A step by step guide to creating new business ideas worth backing*. Harlow, UK: Pearson Education Limited.

Christensen, C. M., & Eyring, H. J. (2011). *The Innovative University: Changing the DNA of Higher Education*. San Francisco, CA: Jossey-Bass.

Christensen, C. M., Horn, M. B., & Johnson, C. W. (2011). *Disrupting Class: How disruptive innovation will change the way the world learns*. New York: McGraw-Hill Education.

Cropley, A. J. (2012). Creativity and education: An Australian perspective. *The International Journal of Creativity & Problem Solving*, *22*(1), 9–25.

Cropley, D. H. (2008). Fostering and measuring creativity and innovation: Individuals, organisations and products. *Mendeley Issue*, *1942*, 267–278.

Cropley, D. H., & Cropley, A. J. (2016). Promoting creativity through assessment: A formative CAA tool for teachers. *Educational Technology Magazine*, *56*(6), 17–24.

De Brabandere, L., & Iny, A. (2013). *A new paradigm for business creativity: Thinking in new boxes*. New York, NY: Random House Publishing Group.

De Villiers, J. M., Duke, L. L., & Jansen van Nieuwenhuizen, P. J. (2017). *The Fourth Industrial Revolution: Highlighting the South African Skills Crisis*. Retrieved March 5, 2019 from https://www.skills-universe.com/2017/10/28/the-fourth-industrial-revolution-highlighting-the-south-african-skills-crisis/

Edublox Online Tutor. (2019). *Cognitive skills: what are they and why they are important?* Retrieved March 5, 2019 from https://www.edubloxtutor.com/tag/cognitive-development/

Epstein, R., Schmidt, S. M., & Warfel, R. (2008). Measuring and training creativity competencies: Validations of a new test. *Creativity Research Journal*, *20*(1), 7–12. doi:10.1080/10400410701839876

Fields, Z., & Atiku, S. O. (2015). Testing and Operationalizing a Model to Measure Creativity at Tertiary Educational Level. *International Journal of Educational Sciences*, *9*(3), 283–296. doi:10.1080/09751122.2015.11890318

Göke, N. (2018). *The Future of Learning*. Retrieved December 15, 2018 from https://medium.com/s/story/what-is-the-future-of-learning-3ff625d1dc86

Graham, L. (2013). *Bouncing back: rewiring your brain for maximum resilience and well-being*. New World Library.

Gray, A. (2016). *The 10 skills you need to thrive in the Fourth Industrial Revolution*. The World Economic Forum. Retrieved February 10, 2019 from https://www.weforum.org/agenda/2016/01/the-10-skills-you-need-to-thrive-in-the-fourth-industrial-revolution/

Henry, J. (Ed.). (1991). *Creative management*. London: SAGE Publications Ltd.

Hughes, R. L., Ginnette, R. C., & Curphy, G. J. (2015). *Leadership: Enhancing lessons of experience* (8th ed.). Singapore: McGraw-Hill Education.

Jezard, A. (2018). *The 3 key skill sets for the workers of 2030.* World Economic Forum. Retrieved February 10, 2019 from https://www.weforum.org/agenda/2018/06/the-3-skill-sets-workers-need-to-develop-between-now-and-2030/

Kaldero, N. (2019). *How to lead a data driven organisation.* Disruption Insights. Retrieved February 10, 2019 from https://disruptionhub.com/how-to-lead-a-data-driven-organisation-nir-kaldero-6327/

LearningRx. (2019). *What are cognitive skills?* Retrieved February 4, 2019 https://www.learningrx.com/what-is-brain-training-/what-are-cognitive-skills-/

MacGregor, K. (2013). *A higher education avalanche is coming, says new report.* University World News: The global window on higher education. Retrieved February 4, 2019 from https://www.universityworldnews.com/post.php?story=20130316093956321

Muff, K. (2013). Developing globally responsible leaders in business schools. *Journal of Management Development*, *32*(5), 487–507. doi:10.1108/02621711311328273

Neuroscience News. (2019). *How the Brain Learns New Skills.* Retrieved February 4, 2019 from https://neurosciencenews.com/skill-learning-brain-13013/

Newsroom. (2019). *Ken Robinson has a theory: School kills creativity (and it must be changed).* Retrieved February 4, 2019 https://www.morningfuture.com/en/article/2019/02/06/ken-robinson-creativity-school/538/

Nuez, R. B. (2018). *By 2020 your skills will be unimportant but why*? Retrieved January 30, 2019 from https://medium.com/@ramonbnuezjr/by-2020-your-skills-will-be-unimportant-but-why-641d1cf3a1ee

Penprase, B. E. (2019). The Fourth Industrial Revolution and Higher Education. In N. W. Gleason (Ed.), *Higher education in the era of the Fourth Industrial Revolution* (pp. 216–228). Singapore: Palgrave Macmillan.

Petrone, P. (2019, January 1). *Why creativity is the most important skill in the world*. [LinkedIn The Learning Blog]. Retrieved February 4, 2019 from https://learning.linkedin.com/blog/top-skills/why-creativity-is-the-most-important-skill-in-the-world

PricewaterhouseCoopers (PwC network). (2018). *Workforce of the future - The competing forces shaping 2030*. Retrieved February 4, 2019 from https://www.pwc.com/gx/en/services/people-organisation/workforce-of-the-future/workforce-of-the-future-the-competing-forces-shaping-2030-pwc.pdf

PricewaterhouseCoopers (PwC network). (2019). *Talent trends 2019: Upskilling for a digital world*. Part of PwC's 22nd Annual Global CEO Survey Trends Series. Retrieved February 4, 2019 from https://www.pwc.com/gx/en/ceo-agenda/ceosurvey/2019/themes/talent-trends.html

Rossouw, D. (Ed.). (2014). *Intellectual tools: Skills for the human sciences* (2nd ed.). Pretoria: Van Schaik Publishers.

Sawyer, K. (2013). *Zig Zag: The surprising path to greater creativity*. San Francisco, CA: Jossey-Bass.

Science of Summit. (2019). *The Science of Summit Report 2018*. Retrieved February 4, 2019 from https://valley.aspenps.org/pdfs/2018_science_of_summit_2.pdf

Soffel, J. (2016). *What are the 21st-century skills every student needs?* World Economic Forum. Retrieved February 4, 2019 from https://www.weforum.org/agenda/2016/03/21st-century-skills-future-jobs-students/

Suri, R. (2018). *The Fourth Industrial Revolution will bring a massive productivity boom*. World Economic Forum. Retrieved February 4, 2019 from https://www.weforum.org/agenda/2018/01/fourth-industrial-revolution-massive-productivity-boom-good/

Trainers Warehouse. (2019). *Zig Zag Creativity Cards*. Retrieved February 4, 2019 from https://www.trainerswarehouse.com/zig-zag-creativity-cards.html

Turak, A. (2011). *Can Creativity Be Taught?* Forbes Leadership. Retrieved February 4, 2019 from https://www.forbes.com/sites/augustturak/2011/05/22/can-creativity-be-taught/#7af2fe761abb

Vandervelde, W. (2018). *When the box is the limit: Drive your creativity with constraints*. Amsterdam: BIS Publishers.

Whetten, D. A., & Cameron, K. S. (2016). *Developing management skills* (9th ed.). Harlow, UK: Pearson Education Limited.

World Economic Forum. (2019). *The future of jobs report: Employment, skills and workforce strategy for the Fourth Industrial Revolution*. Retrieved February 4, 2019 from http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf

Xing, B., & Marwala, T. (2017). Implications of the Fourth Industrial Age for Higher Education. *Science and Technology*, *73*, 10–15.

KEY TERMS AND DEFINITIONS

Caramba: The moment when there is a strong indication that a current mental box must be re-evaluated due to the fact that it is inconsistent with existing approaches, beliefs, paradigms, or boxes.

Converge: Using logical thinking to critically evaluate ideas.

Creative Intelligence: Using divergent thinking to go beyond the existing to create novel and interesting ideas.

Diverge: Using creative thinking to generate creative ideas.

Kleytro™: A creativity training system and the first systematic method for enhancing creative intelligence.

Triple Helix Framework: A model of innovation which refers to a set of interactions between academia, industry, and governments to foster economic and social development.

Whole-Brain Thinking: Combining divergent and convergent thinking to find the best creative ideas that can be practically implemented.

Chapter 6
SMEs in the 4th Industrial Revolution:
Creative Tools to Attract Talents and Shape the Future of Work

Justine Walter
2b AHEAD ThinkTank, Germany

ABSTRACT

Apart from the emergence of new technologies, the Fourth Industrial Revolution is characterized by demographic developments that will provoke fundamental changes in the labor markets of many industrialized countries. This situation will especially affect small and medium-sized enterprises (SMEs) that are based in rural regions with rapidly increasing numbers of retirees and an equally rapidly shrinking population of young people. If these companies want to maintain their levels of production in the Fourth Industrial Revolution, they will need to pursue new creative strategies for attracting the best talents. All of this is true for Saxony, a highly industrialized German region with a large percentage of SMEs that is hit hard by declining birth rates and high levels of emigration, and the East Asian society of Taiwan that faces similar challenges. At the same time, many well-educated members of the young generation in both regions feel disrespected, underpaid, and without prospects.

INTRODUCTION

The 3rd Industrial Revolution has made people a crucial factor for business success of both large corporations and small companies: Companies with committed and

DOI: 10.4018/978-1-5225-9188-7.ch006

engaged employees have substantial competitive advantages that include higher productivity and lower employee turnover (Vance, 2006) as well as greater levels of innovativeness (Xerry, 2013).

Whether or not this will remain true in the 4th Industrial Revolution is yet unclear as emerging intelligent technologies will "drive radical shifts in the way we live […], the way we produce and transport goods and services, the way we communicate, the way we collaborate, and the way we experience the world around us" (Schwab, 2018, pp. 40-41). In its current early stages, however, it is entirely within the power of people to shape the evolution of the 4th Industrial Revolution, seizing the opportunities and mastering the challenges that arise from emerging advanced technology. To do so, societies and companies require people with an understanding of these technologies and their potential, and with a mindset that is adapted to the radical changes that are about to happen.

However, at the onset of the 4th Industrial Revolution the large numbers of Small and Medium-Sized Enterprises (SMEs) in the German federal state of Saxony and in East Asian Taiwan are lacking these people. Confronted with an aging workforce and the continuing emigration of skilled workers, they find it increasingly difficult to recruit candidates with relevant qualifications and mindsets for their open positions (Carl & Gondlach, 2018). In order to remain competitive and transition to the new economic era, SMEs need to start pursuing more innovative and creative approaches for recruiting and retaining young talents with future skills.

Based on the characteristics of SMEs and expectations of recent university graduates in the regions of Saxony and Taiwan, this paper investigates tools with which SMEs can establish an employee experience (EX) and become more attractive for young professionals. To this end, the author will first define the relevant demographic groups, before outlining some particularities of the recruitment, selection and HR development processes in Small and Medium-Sized Enterprises. Subsequently, a holistic concept of Employer Branding and the creation of an employee experience is introduced and tested with two case studies: the recruitment, selection and retention of young professionals in the region of Saxony, Germany, and in Taiwan. In conclusion, some implications for SMEs in these two areas will be drawn.

BACKGROUND

In both regions, the majority of young professionals can be categorised as members of the Generation Y, or gen y. This term was first used in a 1993 article of the US American magazine Advertising Age (Dahlmanns, 2014) and relates to those born after 1980 and before the year 2000. Alternative expressions like "net generation", "generation @", or "digital natives" allude to this generation's increased use of information technology that distinguishes them from their parents and grandparents, the "digital immigrants" who only learned to use the internet in their adult years.[1] However, these terms only insufficiently differentiate the Generation Y from younger age cohorts that have likewise, or to an even greater extent, used modern information technology from an early age on (Rehm, 2014).

Not only the denominations, but also the definitions which authors give for this generation's age span vary significantly: Swedish researcher Parment (2009) gives 1984 to1994 as their birth years, the German study by Ruthus (2014) uses the years from 1980 to 2000, Tulgan (2009), as quoted by Dahlmanns (2014), states they were born between 1978 and 1990, and Allihn (2013) sees them born within the period from 1980 to 1995.

Based on these authors, this paper defines the investigated demographic group as those born between 1980 and the early 1990s. This group is referred to as Gen Y for the German region of Saxony and as Strawberry Generation for Taiwan.

MAIN FOCUS OF THE CHAPTER

Recruitment, Selection And HR Development In Small And Medium-Sized Enterprises

Definition of Small and Medium-Sized Enterprises

The European Union defines Small and Medium-Sized Enterprises (SMEs) as companies with the following features: (Staatsministerium für Wirtschaft, 2015)

- Up to 250 employees
- Up to 50 million € in annual turnover
- Up to 43 million € in total assets.

In addition, enterprises that meet these quantitative features but are completely or partly (more than 25%) owned by larger corporations are not considered as SMEs by the EU's definition.

While quantitative features like these are the most common way to categorise enterprises, SMEs also share qualitative aspects:

The Role of the Entrepreneur

As many SMEs are family-owned businesses, the entrepreneur coins the style of management, working conditions, market strategies, as well as internal and external communication to a significantly bigger extent than in large enterprises.

Priorities

Entrepreneurs and managers in SMEs frequently emphasise finance, production, marketing etc. over HR issues; this is a result of the often limited financial, human and knowledge resources available to SMEs.

Informality

As it is crucial for SMEs to react rapidly to changing conditions in the market, their management of human resources needs to be more flexible and informal than that in larger companies. That is why compensation policies frequently are flexible and training measures tend to be informal and on the job.

These quantitative and qualitative particularities and the limitations in staff and funds significantly affect HR management in SMEs.

Particularities Of HR Management In SMEs

While larger medium-sized enterprises, typically those with more than 100 employees (Dessler, 2015), may be equipped with a HR Department or at least a HR professional, in small enterprises HR activities are usually dealt with by the owner(s) or other employees with good "people skills" on the fly (Ribeiro Novo Melo & Machado, 2014). While in theory this proximity to company leadership enables a closer alignment of HR practices with the strategic goals, in reality, personnel issues are frequently viewed as secondary to other processes and are thus performed only rudimentarily (Dessler, 2015).

The lacking priority of HR issues exacerbates the already existing competitive disadvantages of SMEs compared to large companies: While the latter are already familiar to many potential job candidates through their products or services, costly recruiting campaigns and generous benefits to employees further bolster their perception as good employers. In contrast, many Small and Medium-Sized Enterprises, especially in the engineering sector, are hardly known for their products (at least not outside of expert groups or a limited area) and frequently lack the financial means, human capacities, and necessary knowledge for large-scale recruiting activities (Lohaus & Habermann, 2013).

Nevertheless, recruiting and retaining qualified and motivated employees is a decisive factor for the survival and sustainable success of any business (Brecht & Schmucker, 2014) and of a successful transition to the 4th Industrial Revolution. Creating an employee experience is a holistic approach to achieve this.

From Employer Branding to Employee Experience (EX)

Armstrong (2014, p. 248) understands Employer Branding as the process of creating an Employer Value Proposition (EVP), i.e. "the image presented by an organization as a good employer" that is characterised by "a set of attributes and qualities – often intangible – that make an organization distinctive, promise a particular kind of employment experience and appeal to people who thrive and perform their best in its culture".

Armstrong implies that high-potential candidates can be convinced to apply for a vacancy in any company by features like excellent working conditions, clearly communicated career options or an outstanding incentive system, just like customers can be convinced to buy products of a certain brand because of their high quality, exceptional design or other unique features. Following this approach, HR managers need to "sell" their company to prospective applicants and treat them like customers until they have signed a working contract. This understanding of Employer Branding confines it to the recruitment of employees. As soon as candidates have become part of the company, they get to see the "real picture" just like customers only find out what a product is really like when they first use it.

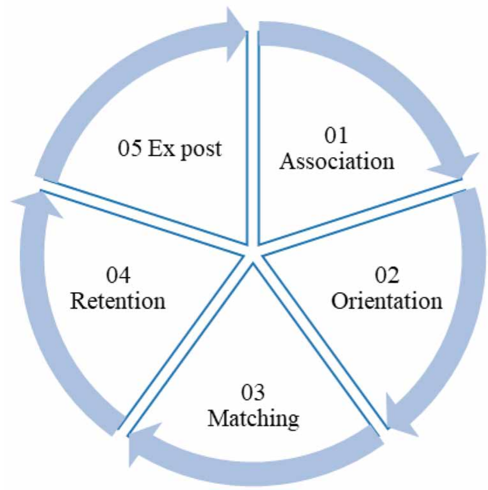
While Armstrong's definition thus mainly aims at making the company widely known among prospective employees, many other authors agree that Employer Branding is more than just a marketing campaign for the company. Rather, it can be described as a holistic process that comprises an external as well as an internal dimension, and continues during, and even beyond, the newly recruited employee's time with the company. German author Radermacher (2013) defines Employer Branding as the process of actively or passively designing an employer's brand or image likewise to the inside and the outside of the company.

According to (Ruthus, 2014), the two central questions that the company, respectively the HR manager, needs to address in this process are:

- Why should an applicant choose our enterprise?
- Why should he stay in the enterprise?

Beck (2012) also considers these two questions central to the process which he subdivides into five consecutive phases: the Association Phase, the Orientation Phase, the Matching phase, the Retention Phase and the Ex-post Phase (cf. Figure 1).

Figure 1. The 5 phases of preference formation
Source: Adapted from Beck (2012: pp 22-25)



Just as customer satisfaction has been superceded by total customer experience in marketing, HR is increasingly focusing on strategies to continuously improve the entire Employee Experience (Mazor et al., 2017).

Its holistic nature and applicability to the recruiting and the retention process, make Beck's 5-phases-model of Employer Branding a valid approach to creating an EX. Before it is tested for the two cases of Saxony and Taiwan, the five phases defined by Beck, as well as their characteristics and the related tasks for the employee and the employer are outlined.

The Association Phase

This first phase can be described as the period of the future employee's secondary and tertiary education. He/she develops basic skills, preferences and expectations of his/her professional life. These attitudes are still largely influenced by parents, friends and teachers/educators. The end of this phase is marked by a tendency or an unspecific decision for a professional field that is subsequently affirmed or revised. (Beck, 2012)

The Orientation Phase

During the orientation phase, the decision that marked the end of the association phase is evaluated in terms of its feasibility. Potential future candidates evaluate their strengths, weaknesses and expectations as well as their career options. The decision that is made at the end of this phase is more specific than that of the previous phase, as potential future applicants define not only their professional field of choice, but also select several enterprises with which they can identify. After sending out applications to these employers of choice, any potential future applicant becomes an actual job candidate. (Beck, 2012)

The Matching Phase

In the matching phase, the candidate and his/her employers of choice evaluate their fit in terms of mutual expectations and options. This is usually done in a situation of face-to-face contact, i.e. in a job interview or an assessment centre. On this basis, both sides decide for or against each other. As the result of a bilaterally positive decision, the previously anonymous candidate becomes an employee. (Beck, 2012)

For SMEs, this first direct contact is crucial for determining whether the candidate is suitable for the enterprise, or not. Many studies have demonstrated that not necessarily the candidates with the best qualifications, but those that fit well into the enterprise are best suited for positions in SMEs. (cf. the subtitle of a recent publication about recruiting and selection in German SMEs „Nicht die Besten sind die Besten, sondern die Geeignetsten" [not the best are the best, but the most suitable ones] (Lohaus & Habermann, 2013))

To achieve this good fit, both the company and the applicant need to be authentic, i.e. communicate their actual strengths, weaknesses and expectations. While the recruiting and selection process ends with the successful completion of the Matching Phase (i.e. the hiring of a new employee), Employer Branding as a holistic HR approach does not stop at this point but needs to continue during the employee's time with the company to create a positive EX. (Athanas, 2017)

The Retention Phase

During his/her employment in the company, the new employee continuously evaluates his/her satisfaction with the tasks he/she is given, as well as the satisfaction with the working climate, the HR activities etc. Only if the result of this evaluation is continuously positive, the employee will stay in the company without looking for alternatives. Consequently, the employer must continue efforts of meeting the employee's expectations, in order to retain him/her. (Beck, 2012)

As both the employees' and the employer's needs and wishes may change over time, it is important that employers continue the dialogue with their personnel long after the initial job interview. This can be done by regular personal feedback rounds or with the additional help of internal or external social platforms where employees, interns and job candidates can share and discuss their experience in the company.

The Ex-Post Phase

This phase begins as soon as the evaluation yields a negative result, either on the part of the employee or on the part of his/her employer. The design of the ex-post phase is largely the responsibility of the former employer and aims at maintaining the former employee's positive image of the company as an employer.

All these phases and the corresponding HR instruments for companies of any size have been summarised in more detail by Beck (2012).

His findings will now be applied to two cases of regions with large numbers of SMEs. In the first case, the German federal state of Saxony will be analysed in terms of its industrial and demographic structure, as well as the structure of its work force. Subsequently, Saxon university students' characteristics and expectations on professional life will be described based on a recent survey. In conclusion, creative HR tools for Saxon SMEs are proposed.

SOLUTIONS AND RECOMMENDATIONS

Case I: Saxony

Industrial Structure And Working Conditions

The Free State of Saxony in the Eastern part of Germany has seen major changes in its industrial structure since the German reunification in 1990. While the Saxon economy was dominated by mining and textile industry for a long time, today the major industries are automobile engineering, machinery production and service industry. Currently, the major German automobile manufacturers Volkswagen, Porsche and BMW all maintain production plants in the Free State. There is tendency of other big companies to settle in the region as well, with their total number having surpassed 600 in 2014 (Staatsministerium für Wirtschaft, 2015). Nevertheless, 99.9% of the circa 150,000 enterprises in Saxony count as SMEs (Staatsministerium für Wirtschaft, 2015) with close to 100% of companies in the agricultural, trading, building and service industries being small or medium-sized. (Staatsministerium für Wirtschaft, 2015)

Accordingly, only 16% of Saxon employees work for big companies, albeit their number has increased by close to 16% since 2009. In contrast, almost one third (30.9%) of the work force are employed by medium-sized enterprises with 50 to 249 employees, even though their share has slightly decreased recently. (Staatsministerium für Wirtschaft, 2015)

In 2013, average wages across different industries amounted to 2,900 Euros. This is only 75% of the German average in the same industries and the same period[2] (Sächsisches Staatsministerium für Wirtschaft, 2016). In consequence, many skilled workers leave Saxony to find a better-remunerated employment in other federal states of Germany, even though in Saxony wages are now slowly rising within many fields. Nevertheless, until this date the on-going emigration of young workers aggravates the difficult demographic situation described below.

Demographic Structure

With 4.081 million inhabitants in 2017 (Statistisches Landesamt, 2017), Saxony has the sixth largest population of all the German federal states and the largest of all the federal states belonging to the former German Democratic Republic.

However, in the years following the German reunification birth rates dropped significantly and only began to recover from the mid-2000s (Sächsisches Staatsministerium für Wirtschaft, 2016). Even though in the years since 2011 the number of births in Saxony has been the highest among all German federal states (Klöppel, 2016), with 36,466 births in 2015 it still has not reached the level of 1990 (Statistisches Landesamt, 2015). At the same time, the average age in the population has increased rapidly over the last 25 years. While the average age was 39.4 years in 1990, estimates have shown that it increased to 46.6 years in 2013, with a tendency to rise further in the next years. (Statisches Landesamt, 2015)

Consequently, in Saxony the demographic developments that are apparent in all of Germany are especially severe. While studies predict that in 2050 the portion of those aged 60 and over will constitute one third of the entire German population, as compared to one fourth today (Weinrich, 2015), in Saxony this situation is projected to arise in 2025 already (Regionalisierte Bevölkerungsprognose, 2015)[3].

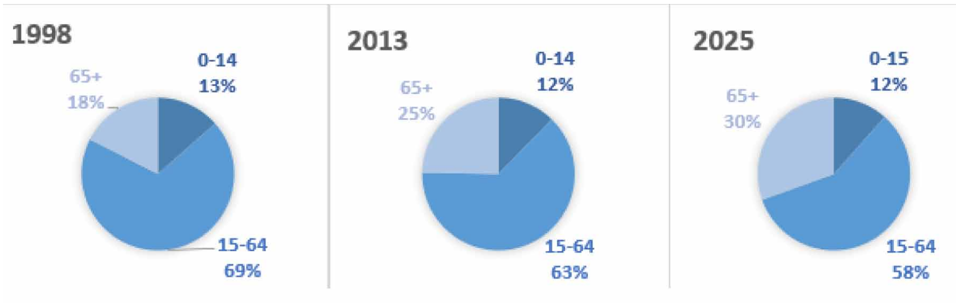
This predicted transformation of the demographic structure and the continuing emigration of young professionals will result in a transformation of the workforce to a yet unknown extent.

Figure 2 graphically depicts this change in age distribution.

Structure Of The Workforce And Methods Of Seeking Employment

Saxony has a well-educated and specialised workforce. In 2015, 19.6% of inhabitants over the age of 15 had a tertiary degree from one of the seven universities in Saxony, or from institutions elsewhere. In 2013, the tertiary graduation rate[4] was as high as 30.4%. (Staatsministerium für Wirtschaft, 2015) Close to 75% of the Saxon population

Figure 2. Distribution of age groups in Saxony in 1998, 2013 and 2025
Source: Adapted from (Sächsisches Landesamt für Statistik, 2015)



of all age groups had completed vocational school. Only 6.8% of the workforce were without any training. (Standort Sachsen im Vergleich mit anderen Regionen, 2016)

Despite the highly qualified workforce, Saxon enterprises struggle with filling their vacancies. From 2005 to 2014, the percentage of vacancies that could not be filled rose from 8 to 27%. While bigger companies with more than 250 employees had less difficulties to find suitable candidates (9%), small enterprises with up to 9 employees could fill little more than half of their vacancies (41%), and enterprises with up to 49, respectively those with up to 249 employees could not fill one in four advertised positions (26% resp. 24%). (Staatsministerium für Wirtschaft, 2015)

At the same time, statistics show that around 8% of the Saxon youth, i.e. those aged 15-24, are unemployed (Brenke, 2013), and that a considerable number of graduates from Saxon universities find their first employment in other German federal states or abroad. (Staatsministerium für Wirtschaft, 2015)

These numbers demonstrate the contradictory situation in Saxony and other German federal states: on the one hand, well-educated, highly motivated young people struggle to find a first position in their home regions, while on the other hand, SMEs especially those located outside of big cities, have substantial difficulties finding sufficiently educated, motivated trainees or employees to fill their vacancies.[5]

In order to tackle this shortage of skilled labour, several initiatives aiming at the generation who left the Free State after the German Reunification to seek better career opportunities in other parts of Germany now promote working in Saxony.

This also becomes apparent in a survey carried out by the Saxon State Office of Statistics, according to which more than 70% of young people aged 16 to 19 are satisfied with their lives in the Free State and would prefer to build a future, while only 29% of highly qualified young Saxons are actively seeking better career options outside of Saxony (sachsen.de, 2017). A 2014 survey among 501 students and graduates of the University of Applied Sciences in Zwickau (Walter & Förster, 2015) also testifies to this contradiction.

Sme Leadership And The Gen Y

The generation that will substantially shape the 4th Industrial Revolution in Saxon SMEs is the Gen Y, i.e. the age cohort born between and the early 1990s.[6]

The Gen Y is depicted as self-confident, but disoriented, striving for security, freedom and flexibility all at the same time, being individualistic but romantic, eager to learn and advance, but bad in concentrating on one thing for a long time, constantly asking for feedback and dialogue, and looking for meaning in everything they do (Ruthus, 2013). Some of these features are reflected in the Gen Y's expectations on their first job as evidenced by the already mentioned survey among students in Zwickau: 99.4% of the participating 501 students of different subjects rated a positive working atmosphere as their priority in choosing a job. Training and development opportunities (96%), work-life balance and job security (both at 94.8%), as well as feedback by superiors (93.4%) were likewise mentioned as crucial expectations by more than 90% of the students. (Walter & Förster, 2015)

What is striking in the survey is that 97.4% of the interviewed students considered appropriate remuneration a crucial factor in their choice of an employer, while only 86.6% emphasised challenging tasks. This seems to contradict the widespread opinion that for the Gen Y, money is secondary to having meaningful, interesting tasks.[7] It can be assumed that this emphasis on remuneration is both a consequence of the low level of wages in Saxony and one of the major factors for many young people's decision to leave the region and find employment abroad.

At the same time, a substantial percentage of the interviewed students preferred to find a first employer in their home region: 52.1% stated they would like to find employment in Central Germany, with another 39.9% narrowing their preference regarding location down to Western Saxony, i.e. the region surrounding their university. Only 10.2% are willing to leave Germany for another European country and 7.4% are prepared to leave Europe completely.

According to the survey, this regional orientation is based on a strong attachment to the region that was felt by 77.5% of the interviewed students. Close ties with their families were an equally significant factor as they caused 75.5% of the students to seek employment in Saxony. Friends followed in the third place (19.5%) but were significantly less important. Landscape and low living expenses (2.5% each), as well as owning property or an apartment in the region (4.5% resp. 3.5%) only played minor roles in the decision about where to look for the first job after graduation.

For employers, these results yield an interesting opportunity: if their professional expectations are taken seriously, many of the Gen Y are willing to stay in Saxony and work in SMEs, even outside of the major cities Dresden and Leipzig. However, this is only possible, if enterprises make themselves known and actively promote their career opportunities to this target audience. The next point discusses tools that can facilitate this process.

HR Tools To Create Employee Experience In Saxon SMEs

As shown above, a substantial number of students at Saxon universities, as well as those attending vocational schools, study subjects that are relevant in the transition to the 4th Industrial Revolution and feel attached to their region. At the same time, a recent survey by Walter and Förster (2015) suggests that the majority of current university students are either indifferent towards the size of their first employer (48%) or even prefer to start their professional life in an SME (39%). Only 13% of the interviewed students favoured a company with more than 500 employees as a first employer.

These results indicate that regional SMEs have all the prerequisites of becoming employers of choice for the Saxon Gen Y, if they manage to create EX customised to this generation.

In the Association Phase

As shown above, young Saxons obtain important career guidance from their families and friends. In the association phase, it is thus important to address parents and their children by sponsoring local sports or cultural activities or by posting adverts in regional magazines or school yearbooks. In the case of Western Saxony and the region surrounding Leipzig, the annual event *Tage der Industriekultur* ("Industrial culture days") presents a suitable, cost-neutral framework to offer company tours that are sure to gain the attention of interested locals and their children, even without a major marketing effort by the company. Supplementing these tours with topical children's entertainment, hands-on activities for students of various age groups or family barbecues in which guests and employees can meet and mingle, will make the company known among those yet unfamiliar with it. Another good way to attract a lot of attention is the placement of adverts, respectively the sponsoring of equipment for annual regional music festivals like the *Kosmonaut* festival in Chemnitz or the *Highfield* festival near Leipzig that are popular with thousands of young people. At these events, also less expensive tools, like postcards with humorous or otherwise eye-catching designs, can help attract the young crowd's attention to a company.

In the Orientation Phase

When actively looking for a job in the orientation phase, the gen y's preferred medium to inform themselves about employers and jobs is the internet. Consequently, it is indispensable for any enterprise to create and maintain a well-structured and well-designed, up-to-date company homepage with an additional career website that is optimised for use with mobile devices and yields information about working conditions, current openings, relevant subjects and ways to apply. In addition, openings should be posted in online job boards that are equally common in looking for employment, even if studies suggest that their impact is currently declining.[8] An upcoming, increasingly relevant method is active social recruiting, i.e. using career networks to find and get in touch with interesting candidates rather than waiting to be found by them. A popular example of a German career network that allows social recruiting for all industries and all career stages is Xing. More specialised networks like Azubiyo, where employers can post and advertise traineeships, also offer a variety of functions to find and connect with suitable candidates.

Another digital way to raise digital natives' awareness of the company are innovative ways of recruiting like posting a challenge to a company-related problem and advertise an award for the best or most creative solution. For instance by using the platform provided by the Saxon start-up whyapp.ly, companies can beat two birds with one stone: they get in touch with young people, who have skills required by the company, but may otherwise be rejected because they lack the formal requirements, and find an innovative solution to a problem without hiring external consultants.

Apart from online resources, many students attend regional job fairs to find out about employers and employment opportunities. For SMEs, these events are an opportunity to present their company, its products and career opportunities. Moreover, annual job fairs like the Horizon job fair in Leipzig, KarriereStart in Dresden, Jobmesse in Chemnitz or ZWIK in Zwickau make it possible for enterprises to meet and personally interact with young people interested in their company.

Moreover, collaboration with regional universities and other educational institutions is an effective way of attracting students' attention. In the framework of internships, joint projects or master's theses, enterprises can get in touch and build a long-term connection with high-potential students. By awarding scholarships like the Deutschlandstipendium[9], employers can further develop relationships with excellent students and simultaneously make themselves known among students as an employer with a positive company culture and a high level of Corporate Social Responsibility (CSR) – two criteria that have been found to be especially relevant to the gen y by several studies (cf. e.g. Mattgey, 2014; Meister, 2012].

In the Matching Phase

The matching phase is the point of direct encounter between employer and potential employee. This contact can be designed as a one-on-one job interview or an assessment centre with several candidates.

At the end of this phase, the employer not only decides, whether the candidate is qualified for the job, but also whether he/she suits the enterprise, i.e. shares company values and can contribute to a positive working atmosphere. To this end, this phase requires authenticity of the employer: only if the company communicates a realistic picture of the job as well as of the company and its mission, it can recruit an employee that will integrate smoothly and perform well. As a positive working climate is university students' top requirement for their future job, recruiting a candidate who is qualified, but does not fit into the company will negatively impact that candidate's EX and the working climate of the entire company.

In order to find a candidate that fits in the company and his/ her future working team, the candidate's prospective supervisor and team members should be incorporated into the selection process and get a chance to be present in the interview(s).

In the Retention Phase

In the retention phase, SMEs need to respond to their new employees' expectations and demands in order to retain them. A positive working atmosphere can be bolstered by pleasant workspaces and by encouraging the social interaction of the employees. For example, this can be done by forming a company sports teams or by organising work outings. Saxony has many scenic sites like the Ore Mountains or the Elbsandsteingebirge that provide opportunities for hiking, climbing and a plethora of other outdoor group activities.

On-boarding programmes for new employees give them the chance to familiarise themselves with all areas of the company and important business processes. This is especially relevant for recent graduates who are new to many aspects of working in a company. Welcome days offer the chance to build a network beyond one's own team by getting in touch with other new employees.

Apart from that, to many young people a good work-life-balance is crucial for job satisfaction. Among the interviewed students from Zwickau, 94,8% stressed this point. Employers can facilitate their employees' work-life-balance by implementing flexible workhours or the option to work from home occasionally. Using up-to-date communication tools like Skype or Adobe Connect, companies can interact with their employees, even if they are absent from the company office.

The findings from above also demonstrate that gen y expect regular feedback from their superior. In contrast to opportunities of training and development that are often externalised and must be funded, supervisors can support employees' professional and personal development easily and cost-neutrally by giving constructive and immediate feedback. An even more effective and likewise economical method is the implementation of mentoring programmes, in which senior employees give advice and support to junior employees. Particularly in the light of the imminent retirement of a large portion of specialised employees in Saxon SMEs, this method will not only help new hires to integrate into the company more easily, but will moreover foster a transfer of valuable knowledge from one generation to the other.

Learning and development will become even more important in the transition to the 4th Industrial Revolution (van Dam, 2017) and are requested by 96% of the interviewed Zwickau students. Opportunities to acquire new skills can be provided using e-learning tools. Platforms like Coursera, EdX or others provide a wide range of courses on business and technical topics in German and English for a moderate price. As e-learning courses can be accessed from anywhere, providing employees with this opportunity does not only give them the feeling of reward. It is also bolsters their work-life-balance as they do not have to travel to take a course at a fixed location and time. Alternatively, companies can create an intranet where they provide learning materials, important company information and forums where employees can exchange news or give feedback to processes within the company.

In the Ex-Post Phase

As the survey among students in Zwickau demonstrated, the reputation of a company among the potential candidates' friends and families is crucial for their decision to apply for a job there. Consequently, enterprises must make sure that former employees maintain and transmit a positive image of their EX in the company. This can be accomplished by a structured exit process, i.e. an exit interview both with employees that are let go, and those that leave on their own choice.

Another tool to maintain a friendly connection with employees regardless of the reason for their leaving, are letters of reference[10] or recommendations that can be attached to future applications. Companies participating in the Empfehlungsbund, a growing network of companies from different industries that now operates nationwide, give former employees (and applicants that were qualified but had to be rejected) a recommendation code that increases their chances to get hired by other participating companies.

Case II: Taiwan

Industrial Structure And Working Conditions

In the second half of the 20th century, economic development in Taiwan accelerated, transforming the then agrarian island into a modern, highly developed and specialised economy. Today, Taiwan is considered one of the Four Asian Tigers (along with Hong Kong, Singapore and South Korea) and regularly listed among the 20 richest countries in the world (CNA, 2015). Today, main industries are IT and Electronics, Chemical, Machinery and Automotive Industry, Biotechnology, and Energy (AHK, 2019). While major IT companies like Asus, Acer, BenQ or Foxconn have developed into multi-national corporations with several thousand employees worldwide, SMEs, that account for roughly 98% of the Taiwanese enterprises, play a major role in the domestic economy as well as in international trade (Taiwan Today, 2015).

Workweeks in Taiwan are significantly longer than in many other countries. Even though the trend towards a decrease in hours worked that can be seen in OECD states is also visible in Taiwan, the average Taiwanese working hours still rank sixth-longest in the world (Huang, 2018). While in 2017 Germans worked an average of 34.4 hours a week (OECD. 2019), official statistics show that in Taiwan the average hours worked per month range between 162.7 in the communications sector and 176.5 in electricity and gas supply (Statistical Bureau, 2017). Various media report that many employers force compulsory overtime on their employees, causing actual work hours in Taiwan to average at 50 hours a week (cf. among others Yang & Pan, 2015).

In addition to these long work hours, wages are comparatively low. In mid-2015, employees earned an average monthly income of NT$ 38,500 or roughly 1,050 Euros (Chen & Huang, 2015). While long-time stable minimum wage has just been raised to NT$ 21,009 (about 590 €), in 2017 70% of regular employees had monthly incomes of under NT$ 40,000 (about 1,100 €), with 40% earning less than NT$ 30,000 (Lu & Wu, 2015). This situation is especially critical for young people, as many of them work on a minimum wage and are entitled neither to days off work nor to work-related benefits. Consequently, many well-educated young people seek employment abroad immediately after graduating from university or after their first years on the job (Lu & Wu, 2015).

Demographic Structure

The emigration of young people aggravates Taiwan's demographic problems. From the beginning of the millennium, the median age of the Taiwanese population has increased rapidly. The first decade saw a rise of almost five years, from 32.9 years in 2000 to 37.5 years in 2010 (2010 Population and Housing Census: Table 2). In 2018, it had already reached 41.3 years (CIA, 2019). This situation is a result of the low fertility rate: With 1.13 births per woman it is the world's third lowest (Statista, 2019). At the same time, life expectancy has increased steadily from 75.8 years in 1998 to 79.9 years in 2013 (National Statistics, 2015).

Consequently, in the decades to come the portion of elderly retired people will grow bigger, while the number of working-age people will decrease (cf. Figure 3).

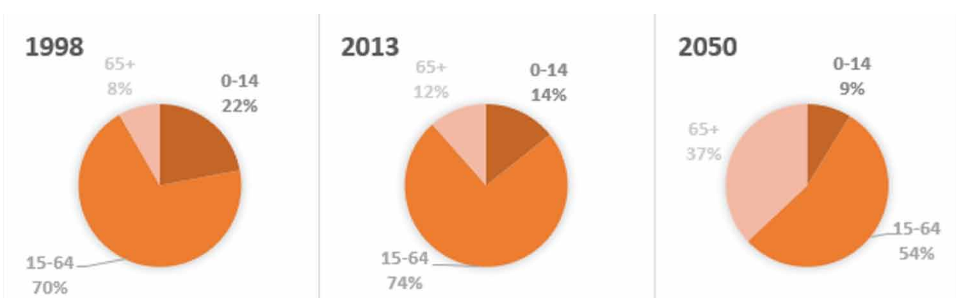
Along with these changes in demography and the emigration of young workers, the structure of the Taiwanese workforce will change drastically. In many sectors, maintaining production will only be possible by recruiting foreign workers or creating EX that attracts well-educated young Taiwanese people, whose to previously unattractive jobs.

The Strawberry Generation And Their Expectations On Professional Life

In Taiwan, the age cohort born in the 1980s (He, 2015) respectively in the 1970s and 1980s (Chou, 2005) is often referred to as Strawberry Generation 草莓族. The term alludes to the young people's alleged similarities with strawberries, which, according to He (美國千禧年世代 vs.臺灣草莓族 (The American Millenials vs. the Taiwanese Strawberry Generation), 2015), is evidenced by the following features:

- Like strawberries that can only grow in a mild climate, this generation emerged from the peaceful climate of late 20th century
- Just like strawberries are a rare and expensive fruit in tropical Taiwan, young people now are a limited and increasingly expensive resource as their numbers do not amount to those of previous generations and they are much better educated

Figure 3. Distribution of age groups in Taiwan 1998, 2013 and 2015
Source: Adapted from Statistical Bureau, 2015.



- However, as soon as the smallest pressure is applied to the strawberry, the skin of the fruit is bruised; in the same way, the strawberry generation is taken to be inept at dealing with even small portions of pressure

Accordingly, older generations often regard this age cohort as spoiled, incapable of working hard and unfit to assume responsibility (Zhou, 2015). In a recent article about the characteristics of Taiwanese university students, business consultant Xie Wenxian (2015), however, comes to conclusion that the Strawberry Generation does not adverse working hard. What distinguishes them from generations before them are their expectations of their working conditions and EX. These expectations can be summarised as "the Five F's (五F)":

Fun, i.e. a cheerful and relaxed working environment
Future, i.e. definite career development schemes
Free, i.e. options to work autonomously
Fast, i.e. the opportunity to quickly obtain a sense of accomplishment
Fair, i.e. to feel respected

Just like the Gen Y, the Taiwanese Strawberry Generation has the qualifications and the potential to become a precious asset in the transition to the 4th Industrial Revolution for any employer willing to respond to their expectations and treat them as equals. However, due to the predominance of the Confucian tradition in Taiwan that stresses the superiority principle to a much larger extent than most European traditions, this process requires a change in social and business culture that cannot be accomplished in the short-run or one-sidedly.

Weinreich (2015) has shown that the most effective way to change company values is the recruiting of candidates who bring the values the company aspires. Thus, in the following some instruments that Taiwanese SMEs can use to recruit Strawberry Generation employees are outlined.

Tools To Attract Young Taiwanese Talents

While there do not exist studies about Taiwanese young people's preferences regarding the size or the location of their future employer, the phases of Employer Branding are the same as for the context of Saxony.

In the Association Phase

As Taiwanese teenagers are much stronger influenced in their career choices by their parents and grandparents, the measures taken in this stage should aim at them.

Companies could e.g. consider holding regular company events to which they invite not only employees but also their spouses, parents and children. Like this, they can advertise themselves as employer of choice with the entire family.

In the Orientation Phase

As demonstrated above, most Taiwanese respond to job adverts that are posted in print media, on television or in online job boards like 104.com.tw or 123.com.tw. Particularly creative adverts or short image videos that are shown on the multitude of screens in the mass transportations systems of Taipei and Kaohsiung, in famous restaurants or on night markets have the potential to attract the attention of many young people and evoke positive associations. The same holds true for adverts in social networks like facebook or job posts on the widely used microblogging service Line. Both have the potential of a major impact as studies have shown that the Taiwanese use their smartphone for a daily average of 197 minutes (AHK, 2015).

Approaching universities by offering cooperation in projects, internships or the option to gain work experience is equally suited to Taiwan as it is to Saxony. In this phase, like in the previous one, it is necessary for SMEs to consider the influence of family members and peer groups. In order to ensure that a positive image of the company as an employer is transmitted, the following matching phase has to be designed well.

In the Matching Phase

The matching phase is the point where applicants and enterprises get in close touch for the first time. In Taiwan, like in Saxony, SMEs mostly rely on a formal application process involving job interviews as the most important tool to evaluate an applicant's suitability. However, other forms of assessment like recruiting events or assessment centres are possible as well. Especially for IT companies, online recruiting games or hackathons that require skills relevant for the job can help to make the application process more attractive for applicants.

Regardless of which tool is used and of whether the recruiting process was successful or not, SMEs should make sure the candidate leaves with a positive experience that he/she can share with friends and family.

In the Retention Phase

The success of the retention phase is determined by how well employer and new employee can agree on the working conditions. As shown above, young Taiwanese find it important to have the opportunity to exchange ideas in a relaxed working environment. (cf. (Liu F., 2015)) While there is no one-fits-all approach to accomplish that, the employer can bolster a positive atmosphere by creating well-lit and comfortable workspaces. Given the importance of food in the Taiwanese culture, providing good, healthy and varied catering as well as rooms where employees can take their meals together will contribute to a favourable working climate and increase the motivation of the employees.

Other instruments to retain young employees are concrete and reliable career development schemes and offers of training programmes or extra-occupational degrees. If young employees can work on tasks autonomously, this will make them feel respected and enable them to develop a sense achievement – two further criteria Xie (2015) has found relevant for their motivation. Individualised skill developments programmes, creative idea management or the gamification of routine tasks may bring fun to work and improve EX.

Given the long work hours and the increasingly criticised role of overtime in the Taiwan's business culture, regular work hours respectively a company culture that strictly limits, or even penalises, rather than encourage, overtime, has the potential to attract positive attention and many applications. Another way to significantly improve working conditions and their perception by employees and thereby retain young employees is the option of home office periods.

Apart from working conditions and job design, remuneration is of crucial importance for young Taiwanese professionals. In order to convince them to stay in the company rather than looking for a job in a bigger company or abroad, SMEs must pay competitive wages that increase after a given period of time (and good performance) in the company. Some financial companies have successfully started to increase wages and grant their high-performing employees additional company stocks (Lin, 2015).

In the Ex-Post Phase

If an employee decides to leave the company, exit interviews allow the company to obtain suggestions for improvement while making the parting employee feel respected. Given the great relevance of personal recommendations and employer reputation in the job search, it is important that former employees keep a positive image of the employer. This will make it more like that the former employee will encourage his/her friends or family members to work for the company.

FUTURE RESEARCH DIRECTIONS

Research into the particularities of HRM processes in SMEs has only started to gain momentum in business research (Harley & Nolan, 2014) and is likely to yield interesting results for the role of smaller companies in the 4th Industrial Revolution.

While this paper focusses on the role of the Gen Y as future leaders in SMEs and shapers of the transition to the 4th Industrial Revolution, empirical research into following generations that have already begun to enter the labour market is another promising field of investigation.

CONCLUSION

In this article, it has been shown that SMEs in Saxony and Taiwan find it hard to recruit and retain young well-qualified people that support their transition to the 4th Industrial Revolution. This is a result of four major factors:

- **Demographic developments**, i.e. the rapid decrease in fertility rates and births in the past decades and the simultaneous increase of life expectancy
- Continuing **emigration** of skilled workers from both regions that (still) exceed the rate of immigration
- Changes in the composition of the available workforce related to the previous conditions, i.e. the **retiring** of large numbers of present employees that leads to an elevated need for new personnel which cannot easily be met, and thus results in a war for talents
- Altered expectations of young people entering the labour market that lead to a **mismatch** between employers and job candidates

Faced with expensive recruiting campaigns and the popularity of large enterprises, SMEs struggle to maintain their standing in these two industrialised economies.

However, an advantage for SMEs can arise from their small size, flexibility, informality of their processes and often "analogue" ways of working. While large enterprises struggle with responding to the young generations' demands, small and medium-sized enterprises can react to them quickly and customise their positions and processes accordingly. Fostering a hands-on mentality in which employees tackle challenges without computer assistance or developing digital tools rather than buying them can facilitate a positive EX.

In addition, SMEs are often firmly rooted in their respective region. Surveys demonstrate that many young people in both Saxony and Taiwan feel closely attached to their homes or study places, and thus regard regional employers a good place to start their careers. Consequently, by developing a positive, customised employee experience SMEs have great potential to attract and retain young, high-performing employees. As both in Saxony and in Taiwan recommendation by families and friends have a crucial influence on a young person's career decisions, creating positive EX, i.e. making current employees feel they work in a great company by creating a pleasant work environment, treating employees with respect or organising team-building challenges, is equally important as external Employer Branding, i.e. the representation of the company as a superb employer to potential applicants. As authenticity of an employer is one of the major criteria for the success of this approach, a long-term, holistic commitment is required.

With some creativity and a human-centred approach to recruiting and retention management, SMEs will find the right people for the transition to the 4th Industrial Revolution.

REFERENCES

Allihn, L. (2013). Gen Y. Kinder unserer Zeit. In H. Künzel (Ed.), *Erfolgsfaktor Employer Branding: Mitarbeiter binden und die Gen Y gewinnen* (pp. 17–34). Berlin: Springer-Verlag. doi:10.1007/978-3-642-40535-8_2

Armstrong, M., & Taylor, S. (2014). *Armstrong's Handbook of Human Resource Management Practice*. London: Kogan Page.

Athanas, C. (2017). Studie zur Candidate Journey: Erfolgreiche Mitarbeiterbindung beginnt im Recruiting. *meta HR Blog*. Retrieved March 31, 2019 from http://blog.metahr.de/2017/01/18/studie-zur-candidate-journey-erfolgreiche-mitarbeiterbindung-beginnt-im-recruiting/

Beck, C. (2012). Personalmarketing 2.0 - Personalmarketing in der nächsten Stufe is Präferenz-Management. In C. Beck (Ed.), *Personalmarketing 2.0. Vom Employer Branding zum Recruiting* (pp. 9–70). Cologne: Luchterhand.

Brecht, S., & Schmucker, H. (2014). Employer Branding im Mittelstand: Strategische Umsetzung bei Wilo. In H. Künzel (Ed.), *Erfolgsfaktor Employer Branding. Mitarbeiter binden und die Gen Y gewinnen* (pp. 201–216). Berlin: Springer-Verlag.

Brenke, K. (2013, May 8). Jugendarbeitslosigkeit sinkt deutlich - regionale Unterschiede verstärken sich. *DIW Wochenbericht*, *19/2013*, 3–13.

Buckesfeld, Y. (2012). *Employer Branding: Strategie für die Steigerung der Arbeitgeberattraktivität in KMU*. Hamburg: Diplomica Verlag.

Carl, M., & Gondlach, K. (2018). *Die Zukunft des deutschen Mittelstandes: Innovationen durch Digitalisierung*. Leipzig: 2b AHEAD.

Central Intelligence Agency. (2019). Taiwan. *The World Fact Book*. Retrieved May 03, 2019 from https://www.cia.gov/library/publications/resources/the-world-factbook/geos/tw.html

Central News Agency. (2015, July 14). Taiwan the 17th richest country in world: Global Finance. *Taiwan News Online*. Retrieved April 01, 2019 from http://www.taiwannews.com.tw/etn/news_content.php?id=2770386&lang=eng_news&cate_rss=news_Economics

Chen, C., & Huang, F. (2015, July 22). Average wages in first 5 months of 2015 up 3.54%. *Focus Taiwan*. Retrieved April 05, 2019 from http://focustaiwan.tw/news/aeco/201507220023.aspx

Dahlmanns, A. (2014). *Generation Y und Personalmanagement*. Munich: Rainer Hampp Verlag.

Dessler, G. (2015). *Human Resource Management*. Harlow: Pearson Education.

Harley, B., & Nolan, C. T. (2014). HRM in Small and Medium Sized Enterprises. In B. Harley & K. Monks (Eds.), *Strategic HRM: Research and Practice in Ireland* (pp. 153–169). Dublin: Orpen Press.

He, M. (2015, September 10). 美國千禧年世代 vs.臺灣草莓族 [The American Millenials vs. the Taiwanese Strawberry Generation]. Retrieved April 15, 2019 from http://homepage.ntu.edu.tw/~msho/public.files/m53.pdf

Hu, E. (2015, December 8). Taiwan's 'Strawberry Generation' Reaches Out To The Young And Trendy. *NPR Parallels*. Retrieved April 15, 2019 from http://www.npr.org/sections/parallels/2015/12/08/458131681/taiwans-strawberry-generation-reaches-out-to-the-young-and-trendy

Huang, T. (2018, April 30). Taiwan has the 6th longest working hours in the world: survey. *Taiwan News*. Retrieved May 2, 2019 from https://www.taiwannews.com.tw/en/news/3418188

Klöppel, M. (2016, November 29). Statistisches Jahrbuch 2016 liegt vor – Einkommen und Geburtenrate im Blick. *Leipziger Volkszeitung Online*. Retrieved April 03, 2019 from http://www.lvz.de/Mitteldeutschland/News/Statistisches-Jahrbuch-2016-liegt-vor-Einkommen-und-Geburtenrate-im-Blick

Lohaus, D., & Habermann, W. (2013). *Personalauswahl im Mittelstand. Nicht die Besten sind die Besten, sondern die Geeignetsten*. Munich: Oldenbourg Verlag. doi:10.1524/9783486754087

Lu, H., & Wu, J. (2015, August 09). Taiwan faces brain drain as wage growth slows: report. *Focus Taiwan*. Retrieved January 20. 2019 from http://focustaiwan.tw/news/aeco/201508090014.aspx

Matheisen, E. (2017, Mai 22). Whitepaper: Bewerber-Reichweite, Karriere-Webseiten und Jobbörsen. *Jobspreader by wollmilchsau Blog*. Retrieved March 29, 2019 from https://wollmilchsau.de/personalmarketing/bewerber-reichweite/

Matheisen, E. (2017, May 3). Webseiten deutscher Industrieunternehmen – Ankunft im digitalen Zeitalter? *Jobspreader by wollmilchsau Blog*. Retrieved March 29, 2019 from https://wollmilchsau.de/karrierewebseiten/webseiten-deutscher-industrieunternehmen-ankunft-im-digitalen-zeitalter/

Mattgey, A. (2014, October 23). Bunte Gen Y: Von taffen Machern und schlaffen Followern. *W&V Studie*. Retrieved March 16, 2019 from https://www.wuv.de/karriere/bunte_gen_y_von_taffen_machern_und_schlaffen_followern

Mazor, A. (2017). The employee experience: Culture, engagement, and beyond. 2017 *Deloitte global human capital trends*. Retrieved May 06, 2019 from https://trendsapp.deloitte.com/reports/2017/global-human-capital-trends/the-employee-experience.html

Meier, F. (2013, September 01). HR in KMU. *HR Today*. Retrieved April 01, 2019 from http://www.steck-hr.ch/docs/S.15-19K_ThemaEinleitungInti9_13.pdf

Meister, J. (2012). The Future Of Work: Corporate Social Responsibility Attracts Top Talent. *Forbes*. Retrieved February 16, 2019 from https://www.forbes.com/sites/jeannemeister/2012/06/07/the-future-of-work-corporate-social-responsiblity-attracts-top-talent/#77ccbd3f954d

OECD. (2019). *Average usual weekly hours worked on the main job*. OECD. Retrieved April 30, 2019 from https://stats.oecd.org/Index.aspx?DatasetCode=STLABOUR

Parment, A. (2009). *Die Generation Y - Mitarbeiter der Zukunft. Herausforderung und Erfolgsfaktor für das Personalmanagement*. Wiesbaden: Gabler. doi:10.1007/978-3-8349-8802-7

Radermacher, S. (2013). Die Herausforderungen des Employer Brandings. In H. Künzel (Ed.), *Erfolgsfaktor Employer Branding. Mitarbeiter binden und die Gen Y gewinnen* (pp. 1–16). Berlin: Springer-Verlag. doi:10.1007/978-3-642-40535-8_1

Rehm, F. (2014). *Web 2.0 im Bereich der Personalbeschaffung*. Munich: Rainer Hampp Verlag.

Ribeiro Novo Melo, P., & Machado, C. F. (2014). *HRM Evolution in SMEs: Recruitment and Selection Case*. Hershey, PA: IGI Global.

Ruthus, J. (2013). *Employer of Choice der Generation Y. Herausforderungen und Erfolgsfaktoren zur Steigerung der Arbeitgeberattraktivität*. Wiesbaden: Gabler. doi:10.1007/978-3-658-04734-4

Ruthus, J. (2014). *Arbeitgeberattraktivität aus Sicht der Generation Y. Handlungsempfehlungen für das Human Resources Management*. Wiesbaden: Gabler.

Sächsisches Staatsministerium für Wirtschaft, Arbeit und Verkehr. (2013, Dezember 9). *Mittelstandsbericht 2011/2012*. Dresden: Land Sachsen.

Sächsisches Staatsministerium für Wirtschaft, Arbeit und Verkehr. (2016a). Mittelstandsbericht 2013/2014. Dresden: Land Sachsen.

Sächsisches Staatsministerium für Wirtschaft, Arbeit und Verkehr. (2016b). Standort Sachsen im Vergleich mit anderen Regionen. Dresden: Land Sachsen.

Schwab, K. (2018). *The Future of the Fourth Industrial Revolution*. London: Penguin Books.

Statisches Landesamt des Freistaates Sachsen. (2015a, September 8). *6. Regionalisierte Bevölkerungsvorausberechnung für den Freistaat Sachsen 2015 bis 2030.* Retrieved April 29, 2019 from https://www.statistik.sachsen.de/download/080_RegBevPrognose_RegEinheiten-PDF/PROG_L_Sachsen_14.pdf

Statisches Landesamt des Freistaates Sachsen. (2015b, September 4). *Geburten und Sterbefälle*. Retrieved April 29, 2019 from http://www.statistik.sachsen.de/html/829.htm

Statisches Landesamt des Freistaates Sachsen. (2017a). *2. Sächsische Wanderungsanalyse. Ergebnisbericht*. Retrieved April 30, 2019 from https://www.statistik.sachsen.de/download/080_SchsWanderungsanalyse/2.SWA_Ergebnisbericht_k.pdf

Statisches Landesamt des Freistaates Sachsen. (2017b, September 30). *Bevölkerungsstand des Freistaates Sachsen nach Kreisfreien Städten und Landkreisen*. Retrieved May 02, 2019 from https://www.statistik.sachsen.de/download/100_Berichte-A/A_I_1_vj3_17_SN.pdf

Statista. (2019). *Countries with the lowest fertility rates in 2017.* Retrieved April 30. 2019 from http://www.statista.com/statistics/268083/countries-with-the-lowest-fertility-rates/

Statistical Bureau, Republic of Taiwan. (2015a, September 10). Manpower Utilization Survey. Retrieved from Table 4. Methods Employed Persons Used to Get Current Jobs, by Year. *National Statistics.* Retrieved April 25, 2019 from http://eng.stat.gov.tw/ct.asp?xItem=37191&CtNode=1659&mp=5

Statistical Bureau, Republic of Taiwan. (2015b, September 11). *Social Indicators 2013. National Statistics.* Retrieved April 25, 2019 from http://eng.stat.gov.tw/public/Attachment/410184513VTN8S5UB.pdf

Statistical Bureau, Republic of Taiwan. (2017). *Yearbook of Earnings and Productivity Statistics. National Statistics*. Retrieved April 25, 2019 from https://eng.stat.gov.tw/ct.asp?mp=5&xItem=42941&ctNode=6235

Taiwan, A. H. K. (2019). *Taiwan: Smart, Innovative, Green*. Retrieved April 30, 2019 from https://taiwan.ahk.de/country-info/taiwan-smart-innovative-green/

Van Dam, N. H. M. (2017). *The 4th Industrial Revolution & the Future of Jobs*. Copenhagen: Bookboon.

Vance, R. (2006). *Employee Engagement and Commitment*. Retrieved May 05, 2019 from: https://www.shrm.org/hr-today/trends-and-forecasting/special-reports-and-expert-views/Documents/Employee-Engagement-Commitment.pdf

Walter, A., & Förster, S. (2015, September 10). Befragung von Studierenden der Westsächsischen Hochschule Zwickau 2014. *FOKUS Prints 04/2015.* Retrieved May 05, 2019 from https://www.tu-chemnitz.de/wirtschaft/bwl6/Materialien/WWW_Publikation/FOKUS-Print_04_15.pdf

Weinrich, K. (2015). *Nachhaltigkeitsorientierte Unternehmensführung. Employer Branding als Ansatz zur Gewinnung geeigneter Mitarbeiter*. Wiesbaden: Gabler.

Xerry, M. J. (2013). *Are committed employees more likely to exhibit innovative behavior: A social exchange perspective* (Doctoral Dissertation). Retrieved May 05, 2019 from https://epubs.scu.edu.au/cgi/viewcontent.cgi?article=1323&context=theses

Xie, W. 謝. (2015, September 11). Who is to say the 80's generation is the strawberry generation! [誰說八年級是草莓族!]. *Business Weekly*. Retrieved May 02, 2019 from http://www.businessweekly.com.tw/KBlogArticle.aspx?id=13841

Yang, C., & Pan, J. (2015, September 11). Taiwanese work many hours of overtime: paper. *Taipei Times Online*. Retrieved April 20. 2019 from http://www.taipeitimes.com/News/taiwan/archives/2013/06/29/2003565940

Zhou, W. (2015, September 09). 這篇是寫給「草莓老人」看的!台灣的老人為什麼這麼沒有競爭力? [This piece is written to be read by the "Strawberry elderly"! Why are the Taiwanese elderly so uncompetitive?]. *Business Weekly*. Retrieved May 02, 2019 from https://www.businessweekly.com.tw/article.aspx?id=13798&type=Blog

ENDNOTES

1 However, the approach to distinguish digital natives from digital immigrants exclusively by means of the birth year is increasingly doubted. Instead, it has been proposed to define digital natives by their use of digital media. By this definition, older people who make extensive use of digital media would also be considered digital natives, while those born after 1980, who prefer to communicate in more "traditional" ways (e.g. phone calls, printing of documents rather than editing them on their smartphones etc.) would count as digital immigrants.

2 Nation-wide, gross wages averaged at ca. 3,880 Euros (Statisches Bundesamt: Verdienste 2018. Retrieved from: https://www.destatis.de/DE/Themen/Arbeit/Verdienste/Verdienste-Verdienstunterschiede/verdienste-branchen.html [20 April 2019].

3 In 2013, the ratio of working-age population: pensioners stood at roughly 3:1, but will reach 2:1 in 2025.

4 The tertiary graduation rate is the percentage of members of one age group that graduate from university or similar institutions of higher education. (Cf. OECD (2017), Population with tertiary education (indicator). doi: 10.1787/0b8f90e9-en (Accessed on 16 January 2019))

5 In the media, this situation is widely discussed as "Fachkräftemangel" (shortage of skilled labour). While there are authors who describe that some companies need to decline commissions as they do not have enough employees to carry them out (cf. e.g. http://www.spiegel.de/wirtschaft/unternehmen/fachkraeftemangel-mittelstand-befuerchtet-umsatzeinbussen-a-1073903.html) and thus increasingly need to rely on foreign workers (cf. e.g. http://www.faz.net/aktuell/beruf-chance/arbeitswelt/fachkraeftemangel-spanier-nach-deutschland-12963536.html), other authors argue that digitalisation and automation will decrease the demand of skilled labour in many economic

fields (cf. e.g. http://www.zeit.de/wirtschaft/2016-03/fachkraeftemangel-als-phantom).
A good example for this is the job platform “Sachse komm zurück”, launched by the Dresden Chamber of Commerce (http://www.sachsekommzurueck.de/servlet/portal?knoten_id=9320&sprache=deu)

6 As human development is most substantially influenced by the environment during teenage and early adult years (Dahlmanns, 2014, p. 17)

7 Cf. The title of a recent publication by K. Bund (2014, Hamburg: Murmann): „Glück schlägt Geld“ (Happiness beats money).

8 In Germany, data reveals that the outreach of online job boards decreased by 26% between April of 2016 and April of 2017 (cf. Matheisen, 2017).

9 The Deutschlandstipendium is a monthly grant of 300€ that is awarded to outstanding university students of all subjects and is financed in equal parts by private sponsors and by the German government; the private sponsor is introduced to the grant recipient by the university and has the option to collaborate with him/her in other activities as well.

10 In Germany, positive letters of recommendation are mandatory by law. By handing out letters that are customised to the employee and elaborate, employers can still show their regret of the employee’s leaving.

Chapter 7
Knowledge Sharing and Creation in Virtual Teams:
An Integrated Framework Based on Distributed Cognition Theory and Transactive Memory Systems

Evi Kneisel
Chemnitz University of Technology, Germany

ABSTRACT

For a more integrative view on social, technical, and individual aspects of knowledge sharing and generation in virtual environments, the current contribution suggests a socio-technical framework based on distributed cognition theory and transactive memory systems. In combination, these well-established social theories provide theoretical foundations for describing and understanding how groups of individuals organize shared activities and interact with technology to store, retrieve, and use individual knowledge for common problem solving and innovation.

INTRODUCTION

The fourth industrial revolution goes hand in hand with massive changes in traditional industries, markets and work places. New forms of technologies and artificial intelligence as well as the omnipresent networking of everything with everything (Richert et al., 2016) lead to the emergence of new forms of work and working environments. As a result, collaboration and networking in virtual environments with teams distributed across company and national borders becomes more and

DOI: 10.4018/978-1-5225-9188-7.ch007

more common. In the future, companies will rely more heavily on virtual teams and networks in order to meet changing customer expectations and needs and to successful navigate in digital environments.

Furthermore, in the context of "Post-Industrialisation" (Drucker, 1993), the primary resource of organisations is moving away from classical tangible production factors towards intangible intellectual assets and digital productivity. The competitiveness of organisations increasingly depends on their ability to manage and harness large amounts of digital information and knowledge for creating innovation and solving complex problems (e.g. McAfee et al., 2012). Additionally, because of digitalisation and automation companies have to come up with more knowledge-intensive work and services, in order to adapt to changing customer needs (Hossain and Lassen, 2017). Against this background, successful knowledge creation and transfer in virtual contexts are crucial for gaining and sustaining competitive advantage in the fourth industrial revolution and are an important field of future research.

At the same time, progressive development of novel technologies promises new possibilities and tools to support critical knowledge processes in virtual collaboration (Schwab, 2017). For example, developments in artificial intelligence, virtual simulation- and virtual collaboration tools, opens up new ways and tools for representing, networking and transferring knowledge among distributed individuals. However, despite emergent technological opportunities, knowledge sharing and knowledge creation in virtual collaboration environments comes with special challenges. Physical distance of team members, cultural diversities and dependence on information technologies complicate knowledge processes (Aritz, Walker & Cardon, 2018; Fiol & O'Conner, 2005; Klitmøller & Lauring 2013). As previous research shows, virtual teams find it harder to overcome social distance between team members and to uncover the team's existing knowledge. As a result, exchange and generation of new knowledge in virtual environments may be more prone to errors and takes more time (e.g. Hayward, 2002; Kauppila, Rajala & Jyrämä, 2011). Virtual teams are thus in a field of tension between growing needs and technological opportunities for virtual knowledge integration on the one side and social challenges of managing knowledge processes over physical, social and cultural distances on the other side. In order to reach effective knowledge processes in virtual teams, both sides, technology and social processes, need to be considered and managed simultaneously.

Although some studies on knowledge processes in virtual teams exists, the field of research is very heterogeneous and lacks of a common and integrative basis (see Fang et al. 2014). Current studies and contributions originate from various domains, especially team performance management, human-computer interaction, knowledge management, organizational learningnand innovation management. Most of these contributions considering a one-sided perspective on knowledge processes in virtual environments, focusing solely either technology components or human factors. However, as technology getting more complex and interactions between individuals and technology getting more complex too, an overarching perspective is necessary, which takes into account the complex relationships and interactions between individual factors (e.g. individual cognition), social factors (interaction and collaboration) and technological factors in virtual collaborations.

For a more integrative view, the current contribution suggests a socio-technical framework based on distributed cognition theory (Hutchins, 1995) and transactive memory systems (Wegner, 1987). Distributive cognition theory applied on various human-technology interactions (e.g. Heersmink & Knight, 2018; Hutchins, 2000, 2014; Hong, 2017; Ley & Seitlinger, 2015) but so far was not used for understanding complex technology mediated knowledge processes in virtual teams. However, the concept is well suited for analysing the interactions among team members and technology in virtual collaborations since it stretches the boundary of cognitive processes beyond the individual's internal processes and accents the interdependencies between individuals in groups and between individuals and artefacts (e.g. technology). While traditional views of information processing and cognition within groups focus on the individual mind as central processor, distributed cognition conceptualize groups and teams as socio-cognitive systems, thereby integrating the social context of cognition (Hutchins 1995, 2000). Within this concept, individuals and technologies considered as elements of a complex cognitive system that goes far beyond them. The theory of transactive memory systems relates to the concept of distributed cognitions since it proposes that individuals tend to rely upon other individuals (or artefacts) to remember things for them. From transactive memory perspective, collective performance depends on coordination of distributed knowledge, partition of knowledge and knowledge related activities among group members. Central basis of effective knowledge coordination is the collective "meta-memory" of the group where members know, how knows what and where knowledge is located.

In sum, the combination of both approaches – distributed cognition theory and transactive memory systems – in a comprehensive framework promises an advanced understanding of knowledge processes in technology-driven environments by making it possible to integrate social, technical and cognitive components.

THEORETICAL BACKGROUND

Research on Knowledge Sharing and Knowledge Generation in Virtual Teams

Virtual teams have become an omnipresent and important form of work organization in today´s companies (Fang et al. 2014; Schiller & Mandviwalla 2007; Siebdrat et al., 2009; Wipawayangkool, 2009). Driven by continuous development and optimization of information technology within the fourth industrial revolution the number of virtual and remote collaborations forms has grown significantly in the last two decades (Fang et al. 2014). Especially in knowledge-intensive, highly dynamic and international sectors, organizations are more and more using virtual teams to be able to operate faster and more flexible (Fang, Kwok & Schroeder, 2014; Schiller & Mandviwalla 2007; Siebdrat, Hoegl & Ernst, 2009). Despite various controversial definitions of virtual teamwork, most researchers consent to the following general characteristics of virtual teams (see also Hertel, Geister & Konradt, 2005; Schiller & Mandviwalla 2007): 1) Virtual team members interact collaboratively and interdependent in order to reach a common goal. 2) Virtual team members are physical (geographically) separated from each other. 3) Communication and interactions between members mainly base on electronic media and information technology, e.g. email, phone, video conferences systems.

The success of virtual teams often relies on their abilities to share and integrate dispersed and diverse knowledge of their members (Fang et al., 2014; Jarvenpaa, Knoll & Leidner, 1998; Yoo & Kanawattanachai, 2001). Effective knowledge processes in teams, in particular transferring and integrating dispersed knowledge, form the basis of organizational and collective learning processes, and are prerequisites for problem solving and innovations (Alavi & Leidner, 2001; Edmondson, 1999; Senge, 1990). Indeed, one main reason for building virtual teams is the prospect of integrating specialized and dispersed knowledge across physical borders in order to keep innovative (Fang et al. 2014).

However, the specific characteristics of virtual collaboration environments can inhibit effective knowledge processes. The dependence on information technology, the spatial separation, cultural differences and low familiarity of team members hinder sharing, integrating and creation of knowledge (Aritz et al., 2018; Fiol & O'Conner, 2005; Klitmøller & Lauring 2013). As sample studies show, knowledge transfer in virtual environments is more prone to errors because the absence of body language or voice tone often lead to misinterpretations in communication (Hayward, 2002; Klitmøller & Lauring 2013). Also uncovering of individual expertise takes more time in virtual teams compared to face-to-face teams (Kauppila, Rajala & Jyrämä, 2011; Koste & Haerem, 2016). Virtual teams are thus in a field of tension between growing needs for knowledge integration on the one side and the social and technical challenges of managing knowledge processes over physical distances on the other side. In order to reach effective knowledge processes virtual teams have to manage simultaneously technological requirements (i.e. selection and use of suitable information technology for collaboration) and social challenges like physical and social distance.

Meanwhile there exist several studies concerning knowledge processes in virtual teams (for an overview see Fang et al. 2014). The existing studies originate from various research fields, particular team management, human-computer interaction, organizational learning and innovation management, and commonly focus on specific factors influencing knowledge sharing or creation in virtual contexts. For example, positive impacts on knowledge creation have been proven by the following factors: virtual team composition (Haas, 2006), structural configuration (Capece & Costa, 2009), communities of practice and situated learning (Robey, Khoo & Powers, 2000) and collaboration expertise development (Majchrzak, Malhotra & John, 2005). Positive influences on virtual knowledge sharing demonstrated the following processes and factors: Collective training (Cornelius & Boos, 2003), effective communication process (Cramton, 2001; Griffith & Neale, 2001; Sole & Applegate, 2000), shared understanding and mutual knowledge (Cornelius & Boos, 2003; Cramton, 2001; Griffith & Neale, 2001) and transactive memory (Griffith & Neale, 2001; Griffith et al., 2003; Yoo & Kanawattanachai, 2001). Despite their interesting findings, the current studies focus solely on single factors and processes, thereby neglecting significant interactions between factors and relevant framing conditions shaping knowledge sharing and creation in virtual teams. Moreover, particular because the studies stem from heterogeneous research fields, there exists no common theoretical basis for integrating current findings on knowledge sharing and creation in virtual teams (see Fang et al., 2014).

The current paper contributes to close this gap. Based on the concepts of distributed cognition theory and transactive memory systems the author conceptualizes an overarching socio-technical framework, which may help integrating heterogeneous findings and influencing factors on knowledge sharing and creation in virtual collaborations.

Distributed Cognition Theory

The working environments of virtual teams are characterized by complex technology-mediated interactions and distribution of tasks and knowledge between people and technology. Distributed cognition theory is well suited for analyzing knowledge processes in virtual collaborations since it stretches the boundary of cognition beyond the individual's internal processes, while focusing on the distributed nature of cognition and knowledge (Hollan, Hutchins & Kirsh, 2000; Hutchins, 1995). From this perspective, virtual teams represent a special type of distributed cognitive systems, in which individual members are dispersed in space, time and knowledge and are connected via communication technology (Hutchins, 2000).

Hutchins developed the concept of distributed cognition in the mid-80s and published it in several articles primarily in the field of Human-Computer-Interaction (HCI) research (e.g. Hutchins, 1995, 2000, 2010, 2011, 2014). Distributed cognition theory does not propose a new type of cognition, rather it takes another perspective on cognition, transcending the individual mind and occurring in a distributed manner (Halverson, 2002). The main assumption is that cognitive processes and knowledge structures emerge at the social level including the physical environments (Artman & Garbis 1998; Heylighen et al., 2004). This, cognition processes and knowledge creation are not limited to the individual minds, but also result of the interactions between individuals and between individuals and cognitive artefacts (Curseu & Rus, 2005). Consequently, the primary unit of analysis is not the individual, but the complete socio-cognitive system, e.g. a virtual team and its environment consisting of people, internal and external artefacts (communication technology) and the connections and interactions between them (Heylighen et al., 2004; Roger & Ellis 1994). Individuals and their cognitions are only one element in this system, “whose structures and processes are distributed between internal and external representations, across a group of individuals, and across space and time” (Zhang & Patel, 2006, p. 333). As cognition emerges as product of coordination between the system elements (Artman & Garbis, 1998), the cognitive qualities of the whole system go far beyond the cognitive attributes of the individual participants of the system.

Moreover, distributed cognition theory views communication technology as a significant element (artefact) within the cognitive system, rather than just a pure communication channel or medium (Hutchins, 1995). Through continuous interactions between individuals and technology, novel knowledge and shared representations (common ground) of individuals emerges (Hutchins, 2000). As a result, the cognitive system as a whole enables access of knowledge that neither a single individual nor a group without technical artefacts could access.

Additionally, distributed cognitive systems involve a shared physical or virtual knowledge space including media (e.g. collaboration technology), in which members share and create knowledge, expertise and mental representations. This collective external environment supports cognitive processes not just passively (as collaboration medium), but rather actively by storing individual and collective knowledge and activities like an external memory (Heylighen, 2014).

Transactive Memory System

Transactive memory refers to a shared division of cognition, which implies the encoding, storage, retrieval, and communication of knowledge from different knowledge domains (Wegner, 1987). Similar to the concept of distributed cognition, the theory of transactive memory proposes that individuals tend to rely upon other individuals or technical artefacts to remember and store knowledge for them. Wegner constitutes that a transactive memory system is “a set of individual memory systems in combination with the communication that takes place between individuals” (Wegner, 1987, p. 186).

The main idea of transactive memory system is that individuals in social relationships develop an implicit mental structure for assigning responsibility for information and knowledge based on their shared representations of each other’s expertise (Austin, 2003; Brandon & Hollingshead, 2004). As result, each member has access to a larger pool of knowledge than he could manage by himself. Originally developed to explain distributed knowledge work in close partnerships, the concept was later expanded to knowledge division in groups, teams and organizations (e.g. Brandon & Hollingshead, 2004).

Transactive memory in groups develops as members get to know the individual expertise and experience of other group members and implicitly or explicitly assign responsibility for expert information to them. Because of allocation of knowledge responsibilities to different members, the existing knowledge in transactive memory systems becomes more specialized or “differentiated” among members over time (Brandon & Hollingshead, 2004; Wegner 1987). Additionally, group members develop shared or “integrated” knowledge (meta-knowledge), which refers to a common understanding of where knowledge is located and “who knows what”. This collective “meta-memory” builds the central basis for effective coordination of distributed knowledge among members fulfilling a common task (Lewis, Lange & Gillis, 2005).

Besides shared and distributed knowledge, communication and interaction between group members plays an important role in the conceptualization of transactive memory systems. Transaction processes forms the basis for encoding, processing and storing knowledge at the group level (Lewis et al., 2003). Moreover, continuous interactions between team members are significant for maintaining and actualization of the distributed knowledge system and knowledge networks (Brandon & Hollingshead, 2004).

Several studies evidence, that effective transactive memory systems in teams enhance knowledge sharing and knowledge creation (e.g. Clark & Dietrich, 2013; Xiongfei & Ahsan, 2018) and relate to higher team performance (e.g. Ren & Argote, 2011; Zhang & Jin, 2010). In addition, first studies in virtual collaboration contexts prove the relevance of transactive memory systems for effective knowledge processes in teams (Imran, Ariff, Sharma & Arshad, 2015; Knapp, 2017).

AN INTEGRATED THEORETICAL FRAMEWORK

Knowledge Sharing and Creation in Virtual Teams in the Light of Distributed Cognition Theory and Transactive Memory Systems

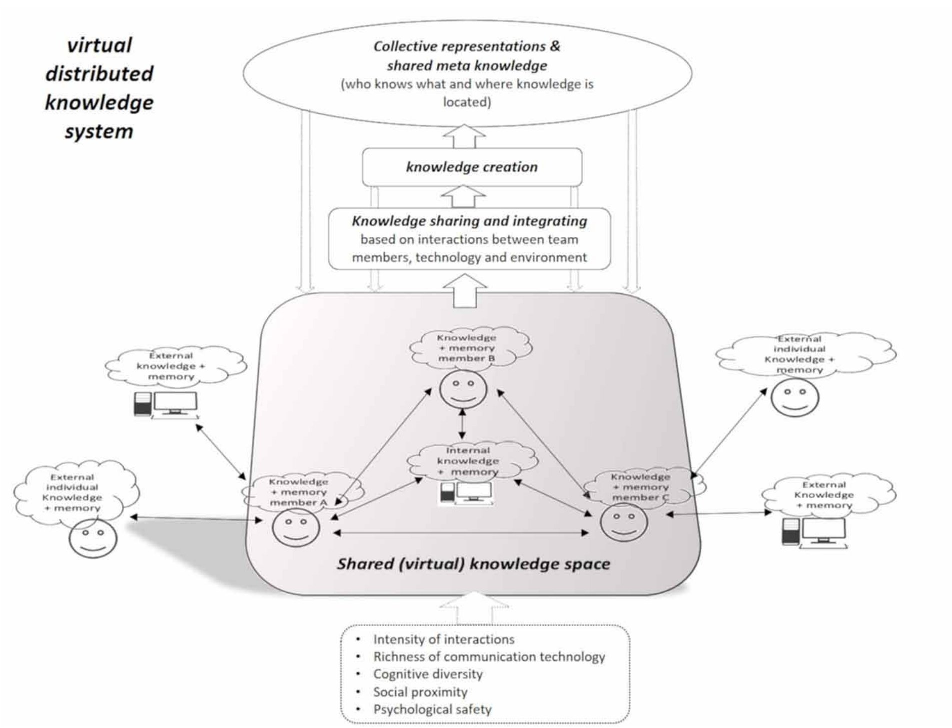
Based on the perspectives of distributed cognition theory and transactive memory systems, an integrative approach of knowledge sharing and creation in virtual teams is proposed. Within this approach, virtual teams and their environments are conceived as complex socio-cognitive systems, called "virtual distributed knowledge systems", consisting of team members, technology (e.g. IT-Tools for collaborating and storing knowledge), external artefacts (e.g. knowledge outside the team) and the connections between these elements. Knowledge sharing and creation taking place within the interactions and transactions between the system´s elements, i.e. between individual members as well as between individuals and technology. Relevant basis for interactions in virtual-distributed knowledge systems is a collective virtual (or physical) knowledge space, which is shared and shaped by team members and used technology. The significance of this virtual-distributed knowledge system is that it enables access of knowledge that neither a single individual nor a team without technical artefacts could access. Thus, individual members know only part of what the team system as a whole may know. Figure 1 presents the integrated approach including relevant components of a distributed knowledge system as well as influencing factors.

The present framework suggests three significant components shaping knowledge sharing and knowledge creation in virtual-distributed knowledge systems, which are explained below: Interactions and Transactions between the system elements, Shared representations and shared memories and Technology as key element and medium of virtual-distributed knowledge systems.

Interactions and Transactions.

The current framework propose that novel knowledge emerges from the nonlinear interactions and transactions between the system´s elements, particular team members, technological artefacts and environment (see Heylighen et al., 2004). Thus, interactions and transactions are a central basis for sharing, integrating and transforming distributed knowledge in virtual teams resulting in renewed individual

Figure 1. Integrated Framework for knowledge sharing and creation in virtual teams: virtual-distributed knowledge systems



and collective representations and understandings, which are stored in the individual and collective memories of the team (i.e. shared representations and memories, see Figure 1) as well as in changed network structures. From this point of view, knowledge creation is considered as a form of collective learning of the whole team system, basing on knowledge sharing in interactions and resulting in changes in cognitive structures of the team, i.e. changes in individual and collective mental models and changes in network structures and memories. That is, knowledge creation occurs not only in the individual minds, but also in the connections and interactions between individuals and technical artefacts. Consequently, virtual teams often can be more intelligent than individual, integrating information from a variety of sources, and overcoming the individual errors and limitations.

Shared Representations And Shared Memories

The common basis of virtual-distributed knowledge systems build the collective representations and shared memories of team members, which emerge from the interactions with the system elements. Through socially distributed processing of task relevant knowledge, team members develop shared representations and expectations about task processing (i.e. shared mental models) as well as shared representations concerning the distribution of knowledge among the internal and external system elements, i.e. shared meta knowledge of who knows what and where knowledge is located. Shared cognitions and memories are central functional components of the whole team system since they form the basis for intersubjective understandings and expectations regarding team and task work (Hutchins, 2000). Furthermore, shared knowledge of who knows what and how the task hast to be fulfilled builds a significant prerequisite for location, coordination and sharing distributed knowledge among team members (Brandon & Hollingshead, 2004). The formation of collective representations is a dynamical and recursive process. Based on continuous processing, transforming and creation of knowledge the collective representations of system members change and adapt accordingly (see also Curseu & Rus 2005). In this sense, the emergence of collective cognition considered as a dynamic representation of collectively created knowledge and perceptions.

Technology

Within virtual-distributed knowledge systems, technology represents a key component taking on three central functions regarding knowledge sharing and creating. First, technology is a significant medium (communication channel) in virtual teams, through which interaction takes place and knowledge is propagated among team members. Since nearly all transactions and communications in virtual teams based on information technology, the kind of used technology significantly shapes the shared physical environment, i.e. the shared virtual knowledge space, in virtual teams. Thus, the features and possibilities of used technology influence the interaction quality and the resulting knowledge processes in virtual teams. Second, technology builds a significant artefact within virtual teams, which forms and transforms knowledge processes. Since cognition and knowledge emerge as products of interaction between individuals and technology, the kind of used technology influence the kind of constructed knowledge of the individual and the whole system. Furthermore, through interactions team members also may change technology particular adapting them for their purpose. Third, used technology (e.g. artificial intelligence) may function as external memory storing collective knowledge and activities of the system. This, technology builds a significant part of the system memory, where knowledge is stored and located.

Factors Influencing Knowledge Sharing And Creation In Virtual Teams

The presented framework based on distributed cognition theory and transactive memory systems further highlights five relevant factors influencing processes of knowledge sharing and knowledge creation in virtual teams (see also Figur 1): Intensity of interactions, Richness of communication technology, Cognitive diversity, Social proximity and Psychological safety.

Intensity of interactions

Knowledge sharing and creation heavily depends upon the interactions among team members and communication technology (Hutchins 2000). Within collective interactions, the team becomes aware of dispersed and heterogeneous knowledge distributed among team members, artefacts and environment. As a result, novel or previously unaccounted knowledge can be uncovered and integrated in collaboration. Furthermore, close interactions support explicit exchange among team members since they stimulate an explicit discussion of knowledge, experiences and expectations regarding task processing. Through sharing and integrating of dispersed knowledge in interactions, new knowledge and understandings emerge. Thus it is assumed, that a high intensity of interaction promotes sharing and creation of knowledge in virtual teams.

Assumption 1: The higher the interaction intensity among team members, the more likely sharing and creation of knowledge takes place.

Richness Of Communication Technology

As mentioned above communication technology builds a key element in virtual-distributed knowledge systems since it is the central medium (communication channel), through which interaction and communication takes place. In consequence, the characteristics and richness of used technology influences interaction quality and effective knowledge sharing among team members. Richness of communication technology (i.e. media richness) refers to the ability of technology to replicate the information sent over it (Daft & Lengel, 1986). A basic assumption is that the richer the media, the more cues and task relevant information are provided (Aritz et al., 2018). Characteristics of high media richness are the ability for using natural language, the possibility of rapid feedback and the ability of using multiple information cues parallel (ebd.). Examples of “richer” media are video- and web-conferencing, telephone and chat. Using rich media supports multiple patterns of information flow in virtual teams, which allows redundant processing of knowledge and creating multiple representations of the same aspect (Hutchins, 2000). Several studies show that communication through rich media, e.g. web conferences, is more appropriate when complex knowledge has to be shared in comparison to simple information (e.g. Daft, Lengel, & Trevino, 1987; Hayward, 2002; Kezsbom, 2000). Thus, it is supposed, that a high richness of communication technology supports knowledge sharing and creation in virtual teams.

Assumption 2: The richer the communication technology used in virtual teams, the more likely sharing and creation of knowledge takes place.

Cognitive Diversity

Cognitive diversity refers to multiplicity of existing knowledge in teams, including different perspectives, expertise and convictions of individual members (Mitchell & Nicholas, 2006a, 2006b). High diversity in depth and type of individual knowledge promotes accumulation of knowledge within in teams, which is a significant prerequisite of knowledge creation. That is, the greater the amount of knowledge a team can potentially access, the higher the likelihood of innovative new knowledge emerging within teams (Mitchell & Nicholas, 2006b). Empirical studies confirm that integrating and synthesising heterogeneous knowledge from diverse expert areas promotes idea generation and innovation (e.g. Bogenrieder, 2002; Nemeth & Nemeth-Brown, 2003; Sutton & Hargardon, 1996). Therefore, it is assumed that high cognitive diversity in virtual teams promotes the creation of new and innovative knowledge.

Assumption 3: The higher the cognitive diversity in virtual teams, the more likely new and innovative knowledge emerges.

Social Proximity

Social proximity refers to the social relationships between team members (Boschma, 2005; Hoödt Christensen & Pederson, 2018) and describes the individual perception of being socially and psychological linked to other persons respectively to other coworkers (e.g. Hubert, 2012; Dampérat, Jeannot, Jongmans & Jolibert, 2016). Social proximity supports collaboration because social relationships between team members creating high levels of trust and thus reducing the social costs of interaction and knowledge sharing (Caniëls, Kronenberg, and Werker 2014; Reagans, 2011). Furthermore, high social proximity implies “shared informal rules and habits” (Caniëls, Kronenberg, and Werker 2014, p. 225) and supports mutual understandings and a shared language between team members (Ooms, Werker & Caniels, 2018; Hoödt Christensen & Pederson, 2018), which are significant prerequisite for effective collaboration and knowledge sharing. Social relationships also increase the awareness of who knows what (Hoödt Christensen & Pederson, 2018), thereby reducing the expenditure of searching and locating specialized knowledge in teams. In sum, high social proximity has a positive effect on collaboration in virtual teams resulting in better conditions for knowledge sharing and creating.

Assumption 4: The higher the social proximity among team members, the more likely sharing and creation of new knowledge takes place.

Psychological Safety

Edmondson (1999) proposed the construct of psychological safety as prerequisite for effective team learning and change and described it as "a shared belief held by members that the team is safe for interpersonal risk taking". High psychological safety implies a climate of mutual trust and respect in teams, which is a significant basis for "fearless" and confident speaking up and discussing individual opinions and experiences within groups (Edmondson, 2002; Knoll & Gill, 2011). Under conditions of perceived mental freedom and a supportive climate in cognitive systems, participants will be more likely to interact with others and to share and integrate individual knowledge (see also Hutchins 1995; cognition in the wild). Several studies confirmed positive relationships between psychological safety and willingness to share knowledge in collaborative interactions (e.g. Kessel, Kratzer & Schultz, 2012; Siemsen, Roth, Balasubramanian & Anand, 2009; Zhang, Fang, Wei & & Chen, 2010). Therefore, it is supposed, that a climate of high psychological safety in virtual teams supports fruitful interaction processes and the sharing and creation of knowledge in teams.

Assumption 5: The higher the psychological safety in virtual teams, the more likely sharing and creation of new knowledge takes place.

CONCLUSION AND RECOMMENDATIONS

Summary and Discussion

Knowledge sharing and knowledge creation are key success factors of virtual teams as they build the basis for collective learning, effective problem solving and innovation. However, particular because of the virtual and technical environment, knowledge processes in virtual collaborations comes with various challenges. In addition to technological requirements, virtual teams have to manage complex social and cognitive processes in order to reach effective knowledge processes. For a better understanding and managing of virtual knowledge processes, the current paper for the first time conceptualizes an overarching framework considering social, technical and cognitive aspects. Based on distributed cognition theory and transactive memory systems the socio-technical framework describes relevant components of virtual distributed knowledge systems and proposes significant factors influencing knowledge sharing and knowledge creation in virtual teams. The significance of this framework is that it takes account of multiple factors (social, technical and cognitive aspects) shaping and influencing virtual knowledge processes.

Contributions to the Literature

This paper provides several contributions to theory and practice. From a theoretical perspective, the present framework integrates research and concepts regarding knowledge management, transactive memory, distributed cognition and virtual teams in order to advance current understandings of knowledge sharing and creation in virtual collaborations. Insights from distributed cognition theory and transactive memory systems enables recognizing the socially constructed nature of knowledge in teams and describing how the processing of knowledge in virtual, technology mediated interactions takes place. Based on collective memory of who knows what and where expertise is located team members gain access to an amount of knowledge to enhance collective interactions and knowledge creation.

Further, by conceptualizing the connection between distributed cognition and Transactive Memory Systems the paper contributes to a more comprehensive view on virtual knowledge processes. For the first time, technical, social and cognitive aspects of knowledge sharing and creation in virtual environments have been considered integrative. This may serve as first step into a common theoretical basis for studying knowledge processes in virtual collaboration environments.

A viable path for future research is the empirical testing and specifying of the assumptions formulated within this paper. As a prerequisite the present framework hast to be transformed into a research model with specific and testable hypotheses. The present assumptions on influencing factors on knowledge sharing and creation in virtual teams form a first starting point for this.

Implications for Organisational Practice

In practical terms, when attempting to implement efficient knowledge sharing and creation processes, virtual team leaders have to take account for multiple factors, finding a suitable fit between social, technological and individual (cognitive) aspects. Further, the five influencing factors on knowledge sharing and knowledge creation in virtual teams advanced in this paper can assist team leaders in the identification and management of conditions that are encouraging effective knowledge processes in virtual collaborations. The recognition that intensive interactions, richness of communication technology, knowledge diversity as well as helpful social climate and relations among team members contribute to sharing and creation of knowledge in different ways may support leader's decisions for team management and team composition.

REFERENCES

Alavi, M., & Leidner, D. E. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. *Management Information Systems Quarterly*, *25*(1), 107–136. doi:10.2307/3250961

Argote, L., & Guo, J. M. (2016). Routines and transactive memory systems: Creating, coordinating, retaining, and transferring knowledge in organizations. *Research in Organizational Behavior*, *36*, 65–84. doi:10.1016/j.riob.2016.10.002

Aritz, J., Walker, R., & Cardon, P. W. (2018). Media Use in Virtual Teams of Varying Levels of Coordination. *Business and Professional Communication Quarterly*, *81*(2), 222–243. doi:10.1177/2329490617723114

Arman, H., & Garbis, C. (1998). Situation Awareness as Distributed Cognition. *ECCE 9: Proceedings of the Ninth European Conference on Cognitive Ergonomics*, 151–156.

Austin, J. R. (2003). Transactive memory in organizational groups: The effects of content, consensus, specialization, and accuracy on group performance. *The Journal of Applied Psychology*, *88*(5), 866–878. doi:10.1037/0021-9010.88.5.866 PMID:14516250

Bogenrieder, I. (2002). Social Architecture as a Prerequisite for Organizational Learning. *Management Learning*, *33*, 197-212.

Boschma, R. A. (2005). Proximity and Innovation: A Critical Assessment. *Regional Studies*, *39*(1), 61–74. doi:10.1080/0034340052000320887

Brandon, D. P., & Hollingshead, A. B. (2004). Transactive Memory Systems in Organizations: Matching Tasks, Expertise, and People. *Organization Science*, *15*(6), 633–644. doi:10.1287/orsc.1040.0069

Capece, G., & Costa, R. (2009). Measuring knowledge creation in virtual teams through the social network analysis. *Knowledge Management Research and Practice*, *7*(4), 329–338. doi:10.1057/kmrp.2009.25

Cornelius, C., & Boos, M. (2003). Enhancing mutual understanding in synchronous computer-mediated communication by training: Trade-offs in judgmental tasks. *Communication Research*, *30*(2), 147–177. doi:10.1177/0093650202250874

Cramton, C. D. (2001). The mutual knowledge problem and its consequences for dispersed collaboration. *Organization Science*, *12*(3), 346–371. doi:10.1287/orsc.12.3.346.10098

Curşeu, P. L., & Rus, D. (2005). The cognitive complexity of groups A critical look at team cognition research. *Cogniţie Creier Comportament*, *9*(4), 681–710.

Daft, R. L., & Lengel, R. H. (1986). Organizational information requirements, media richness and structural design. *Management Science*, *32*(5), 554–571. doi:10.1287/mnsc.32.5.554

Dampérat, M., Jeannot, F., Jongmans, E., & Jolibert, A. (2016). Team creativity: Creative self-efficacy, creative collective efficacy and their determinants. *Recherche et Applications en Marketing*, *31*(3), 6–25. doi:10.1177/2051570716650164

Drucker, P. F. (1993). *Post-Capitalist Society*. Oxford, UK: Elsevier Butterworth Heinemann.

Edmondson, A. (1999). Psychological Safety and Learning Behavior in Work Team. *Administrative Science Quarterly*, *44*(2), 350–383. doi:10.2307/2666999

Edmondson, A. (2002). The local and variegated nature of learning in organizations: A group-level perspective. *Organization Science*, *13*(2), 128–146. doi:10.1287/orsc.13.2.128.530

Fang, Y., Kwok, R. C.-W., & Schroeder, A. (2014). Knowledge processes in virtual teams: Consolidating the evidence. *Behaviour & Information Technology*, *33*(5), 486–501. doi:10.1080/0144929X.2012.719033

Fiol, C. M., & O'Connor, E. J. (2005). Identification in Face-to-Face, Hybrid, and Pure Virtual Teams: Untangling the Contradictions. *Organization Science*, *16*(1), 19–32. doi:10.1287/orsc.1040.0101

Griffith, T. L., & Neale, M. A. (2001). Information processing in traditional, hybrid and virtual teams: From nascent knowledge to transactive memory. *Research in Organizational Behavior*, *23*, 379–421. doi:10.1016/S0191-3085(01)23009-3

Haas, M. R. (2006). Acquiring and applying knowledge in transnational teams: The roles of cosmopolitans and locals. *Organization Science*, *17*(3), 367–384. doi:10.1287/orsc.1060.0187

Halverson, C. A. (2002). Activity Theory and Distributed Cognition: Or What Does CSCW Need to DO with Theories? *Computer Supported Cooperative Work: The Journal of Collaborative Computing*, *11*(1/2), 243–267. doi:10.1023/A:1015298005381

Hayward, P. (2002). A comparison of face-to-face and virtual software development teams. *Team Performance Management*, *8*(1/2), 39–48. doi:10.1108/13527590210425077

Heersmink, R., & Knight, S. (2018). Distributed learning: Educating and assessing extended cognitive systems. *Philosophical Psychology*, *31*(6), 969–990. doi:10.1080/09515089.2018.1469122

Hertel, G., Geister, S., & Konradt, U. (2005). Managing virtual teams: A review of current empirical research. *Human Resource Management Review*, *15*(1), 69–95. doi:10.1016/j.hrmr.2005.01.002

Heylighen, F., Heath, M. & Van, F. (2004). The Emergence of Distributed Cognition: a conceptual framework. *Proceedings of Collective Intentionality IV.*

Holdt Christensen, P., & Pedersen, T. (2018). The dual influences of proximity on knowledge sharing. *Journal of Knowledge Management*, *22*(8), 1782–1802. doi:10.1108/JKM-03-2018-0211

Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed cognition: Toward a new foundation for human-computer interaction research. *ACM Transactions on Computer-Human Interaction*, *7*(2), 174–196. doi:10.1145/353485.353487

Hong, C. (2017). Design of human-computer interaction interface considering user friendliness. *International Journal of Reasoning-Based Intelligent Systems*, *9*(3), 162–169. doi:10.1504/IJRIS.2017.090044

Hutchins, E. (1995). *Cognition in the Wild*. Cambridge, MA: MIT Press.

Hutchins, E. (2000). The Cognitive Consequences of Patterns of Information Flow. *Intellectica*, *1*(30), 53–74. doi:10.3406/intel.2000.1593

Hutchins, E. (2010). Cognitive ecology. *Topics in Cognitive Science*, *2*(4), 705–715. doi:10.1111/j.1756-8765.2010.01089.x PMID:25164051

Hutchins, E. (2011). Enculturating the Supersized Mind. *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, *152*(3), 437–446. doi:10.100711098-010-9599-8

Hutchins, E. (2014). The cultural ecosystem of human cognition. *Philosophical Psychology*, *27*(1), 34–49. doi:10.1080/09515089.2013.830548

Imran, M., Ariff, M., Sharma, R., & Arshad, N. I. (2015). Exploring the Role of Transactive Memory Systems in Virtual Teams: Review and synthesis of literature. *International Symposium on Mathematical Sciences and Computing Research (iSMSC)* 10.1109/ISMSC.2015.7594070

Jarvenpaa, S. L., Knoll, K., & Leidner, D. E. (1998). Is anybody out there? The implications of trust in global virtual teams. *Journal of Management Information Systems*, *14*(4), 29–64. doi:10.1080/07421222.1998.11518185

Kauppila, O., Rajala, R., & Jyrämä, A. (2011). Knowledge sharing through virtual teams across borders and boundaries. *Management Learning*, *42*(4), 395–418. doi:10.1177/1350507610389685

Kessel, M., Kratzer, J., & Schultz, C. (2012). Psychological Safety, Knowledge Sharing, and Creative Performance in Healthcare Teams. *Creativity and Innovation Management*, *21*(2), 147–157. doi:10.1111/j.1467-8691.2012.00635.x

Kezsbom, D. (2000). Creating teamwork in virtual teams. *Cost Engeneering*, *42*, 33–36.

Klitmøller, A., & Lauring, J. (2013). When global virtual teams share knowledge: Media richness, cultural difference and language commonality. *Journal of World Business*, *48*(3), 398–406. doi:10.1016/j.jwb.2012.07.023

Knapp, R. J. (2017). The effects of psychological safety, team efficacy, and transactive memory system development on team learning behavior in virtual work teams. *Dissertation Abstracts International. A, The Humanities and Social Sciences*.

Knoll, D. L., & Gill, H. (2011). Antecedents of trust in supervisors, subordinates, and peers. *Journal of Managerial Psychology*, *26*(4), 313–330. doi:10.1108/02683941111124845

Koste, D., & Haerem, T. (2016). Transactive memory systems in virtual teams: The effect of integration and differentiation on performance. *Academy of Management Annual Meeting Proceedings*, *2016*(1), 1-6.

Lewis, K., Lange, D., & Gillis, L. (2005). Transactive Memory Systems, Learning, and Learning Transfer. *Organization Science*, *16*(6), 581–598. doi:10.1287/orsc.1050.0143

Ley, T., & Seitlinger, P. (2015). Dynamics of human categorization in a collaborative tagging system: How social processes of semantic stabilization shape individual sensemaking. *Computers in Human Behavior*, *51*, 140–151. doi:10.1016/j.chb.2015.04.053 PMID:26566299

Majchrzak, A., Malhotra, A., & John, R. (2005). Perceived individual collaboration know-how development through information technology-enabled contextualization: Evidence from distributed teams. *Information Systems Research*, *16*(1), 9–27. doi:10.1287/isre.1050.0044

McAfee, A., Brynjolfsson, E., Davenport, T. H., Patil, D. J., & Barton, D. (2012). Big data: The management revolution. *Harvard Business Review*, *90*(10), 60–68. PMID:23074865

Mitchell, R., & Nicholas, S. (2006a). Knowledge creation through boundary-spanning. *Knowledge Management Research and Practice*, *4*(4), 310–318. doi:10.1057/palgrave.kmrp.8500113

Mitchell, R., & Nicholas, S. (2006b). Knowledge Creation in Groups: The Value of Cognitive Diversity, Transactive Memory and Open-mindedness Norms. *Electronic Journal of Knowledge Management*, *4*(1), 67–74.

Nemeth, C. J., & Nemeth-Brown, B. (2003). Better than individuals? The potential benefits of dissent and diversity for group creativity. In P. B. Paulus (Ed.), Group creativity: Innovation through collaboration, (pp. 63-84). London: Oxford University Press.

Ooms, W., Werker, C., & Caniels, M. (2018). Personal and Social Proximity Empowering Collaborations: The Glue of Knowledge Networks. *Industry and Innovation*, *25*(9), 833–840. doi:10.1080/13662716.2018.1493983

Reagans, R. (2011). Close encounters: Analyzing how social similarity and propinquity contribute to strong network connections. *Organization Science*, *22*(4), 835–849. doi:10.1287/orsc.1100.0587

Ren, Y., & Argote, L. (2011). Transactive memory systems 1985-2010: An integrative framework of key dimensions, antecedents, and con-sequences. *The Academy of Management Annals*, *5*(1), 189–229. doi:10.1080/19416520.2011.590300

Richert, A., Shehadeh, M., Plumanns, L., Groß, K., Schuster, K., & Jeschke, S. (2016, April). Educating engineers for industry 4.0: Virtual worlds and human-robot-teams: Empirical studies towards a new educational age. In *2016 IEEE Global Engineering Education Conference (EDUCON)* (pp. 142-149). IEEE. 10.1109/EDUCON.2016.7474545

Robey, D., Khoo, H. M., & Powers, C. (2000). Situated learning in cross-functional virtual teams. *IEEE Transactions on Professional Communication*, *43*(1), 51–66. doi:10.1109/47.826416

Rogers, Y., & Ellis, J. (1994). Distributed Cognition: An alternative framework for analysing and explaining collaborative working. *Journal of Information Technology*, *9*(2), 119–128. doi:10.1177/026839629400900203

Schiller, S. Z., & Mandviwalla, M. (2007). Virtual Team Research: An Analysis of Theory Use and a Framework for Theory Appropriation. *Small Group Research*, *38*(1), 12–59. doi:10.1177/1046496406297035

Schwab, K. (2017). *The fourth industrial revolution*. Currency.

Senge, P. M. (1990). *The fifth discipline: The art and practice of the learning organization*. New York, NY: Doubleday.

Siebdrat, F., Hoegl, M., & Ernst, H. (2009). How to manage virtual teams. *MIT Sloan Management Review*, *50*(4), 63–68.

Siemsen, E., Roth, A. V., Balasubramanian, S., & Anand, G. (2009). The Influence of Psychological Safety and Confidence in Knowledge on Employee Knowledge Sharing. *Manufacturing & Service Operations Management: M & SOM*, *11*(3), 429–447. doi:10.1287/msom.1080.0233

Sole, D., & Applegate, L. (2000). Knowledge Sharing Practices and Technology Use Norms in Dispersed Development Teams. *International Conference on Information Systems*.

Sutton, R., & Hargadon, A. B. (1996). Brainstorming groups in context: Effectiveness in a product design firm. *Administrative Science Quarterly*, *41*(4), 685–718. doi:10.2307/2393872

Wegner, D. M. (1987). Transactive memory: A contemporary analysis of the group mind. In B. Mullen & G. R. Goethals (Eds.), Theories of group behaviour, (pp. 185-208). New York: Springer-Verlag. doi:10.1007/978-1-4612-4634-3_9

Wipawayangkool, K. (2009). Toward a General Model of Knowledge Creation in Virtual Teams. *Journal of Information & Knowledge Management*, *8*(1), 45–51. doi:10.1142/S0219649209002233

Xiaogang, C., Xue, L., Clark, J. G., & Dietrich, G. B. (2013). Knowledge sharing in open source software project teams: A transactive memory system perspective. *International Journal of Information Management*, *33*(3), 553–563. doi:10.1016/j.ijinfomgt.2013.01.008

Xiongfei, C., & Ahsan, A. (2018). Enhancing team creative performance through social media and transactive memory system. *International Journal of Information Management*, *39*, 69–79. doi:10.1016/j.ijinfomgt.2017.11.009

Yoo, Y., & Kanawattanachai, P. (2001). Developments of transactive memory systems and collective mind in virtual teams. *The International Journal of Organizational Analysis*, *9*(2), 187–208. doi:10.1108/eb028933

Zhang, J., & Patel, V. L. (2006). Distributed cognition, representation, and affordance. *Pragmatics & Cognition*, *14*(2), 333–341. doi:10.1075/pc.14.2.12zha

Zhang, L. Y., & Jin, Y. H. 2010. The Influence of Transactive Memory System on Team Effectiveness. *International Conference on Information Management, Innovation Management and Industrial Engineering (ICIII)*, 18-22. 10.1109/ICIII.2010.483

Zhang, Y., Fang, Y., Wei, K.-K., & Chen, H. (2010). Exploring the role of psychological safety in promoting the intention to continue sharing knowledge in virtual communities. *International Journal of Information Management*, *30*(5), 425–436. doi:10.1016/j.ijinfomgt.2010.02.003

Chapter 8
Knowledge Management and the Digital Native Enterprise

Deonie Francesca Botha
Deloitte & Touche, South Africa

ABSTRACT

This chapter will provide insights into the positioning and manifestation of knowledge management in a digital native enterprise. The findings of the literature review will be enhanced with the findings from three use cases reflecting on the infliction point between knowledge management and work performed in the digital native enterprise. The aforementioned will enable early insights into the role and contribution of knowledge management in an ecosystem where people and devices are seamlessly connected and strategic decisions are needed in respect of the positioning and manifestation of knowledge management, as well as the skillfulness required by knowledge managers within the construct of the digital native enterprise.

INTRODUCTION

Technology is changing the way people perform work, hence the operating models of organisations will need to be re-evaluated and adjusted within the predictable future. Bhalla, Dyrcks and Strack (2017) states "a tidal way of change is coming that will soon make the way we work almost unrecognizable to today's business leaders. In an age of rapidly evolving technologies, business models, demographics, and even workplace attitudes – all shifting concurrently – change is not only constant but also exponential in its pace and scope." These changes result from the Fourth Industrial Revolution (4IR) and its emphasis on technological innovation and digital productivity in digital native enterprises (DNEs). Schwab (2016) continues

DOI: 10.4018/978-1-5225-9188-7.ch008

by describing the extent and nature of the 4IR "In its scale, scope and complexity, what I consider to be the fourth industrial revolution is unlike anything humankind has experienced before. We have yet to grasp fully the speed and breadth of this new [fourth] revolution.

Although the impact of the 4IR on the operating models of organisations is not yet fully comprehendible it is evident that the expectations of clients and society at large will be such that organisations will need to be redesigned. Rosen et al. (2017) is of the opinion that "Digital transformation has progressed to where it is now an existential concern for many enterprises. Growing organisations strive to become "digital native" in the way they think, what they produce, and how they operate. Yet many organisations have difficulty in imagining what the new digital future could be."

Timperley (2018) indicates that although technological and digital productivity have been a gradual process it will require workers to acquire an altered state of skilfulness and mindfulness. Workers need to find a new "state of competitiveness" in the so-called gig economy simply because the rules of employment engagement has changed. In this economy, employment opportunities will not be awarded on the experience or qualifications of workers but rather on their ability to perform work which machines are unable to do. Furthermore, workers need to create and develop the ability to work alongside and collaborate with machines that are able to learn, make decisions and perform a variety of cognitive functions. The aforementioned is of particular relevance to the manifestation and sustainability of knowledge management functions in DNEs.

DNEs will be characterised by formalised and explicit knowledge management strategies that are seamlessly integrated with organisation wide systems and embedded within workflows. These knowledge management strategies combine codification and personalisation approaches and allow for knowledge management initiatives to enable the improved productivity of workers and encourage ecosystem wide innovation (Venkitachalam & Willmot, 2017). Knowledge management should therefore form an integral part of the construct of operational functions organisations. However, in the DNE, "knowledge" will be in the form of "big data" received by sensors and transmitted to actuators and can be analysed in a cloud-based cyber-physical system (CPS). The analyses of big data sets will enable the seamless integration of the products developed and services delivered by organisations and society. All with relatively little intervention from workers and a low dependency on their ability to apply their acquired knowledge and experience to perform knowledge work or physical labour.

The primary objective of this Chapter is to develop insight into the positioning and manifestation of Knowledge management in a DNE. In an effort to achieve the aforementioned objective, Knowledge management in traditional organisations will be juxtaposed with the same in the setting of DNEs. This juxtaposition is augmented by a deliberation on the fundamental concepts that determine the nature of the relationship and the resultant expectancies between DNEs and Knowledge management. The afore is followed by an analysis of three use cases reflecting on the nature of the engagement between Knowledge management and the constructs of "work", "work processes" and the "worker" in a DNE setting. The aim of the deliberation is to analyse the design principles of a DNE as well as the work that needs to be performed in the same in an effort to ascertain the relevancy and future manifestation of Knowledge management.

The hypothesis is the proliferation of data in a DNE will contribute towards an increase in the relevancy of personalisation in a DNE as cyber-physical systems (CPSs) will largely make the need for codification redundant. Data will "flow" into organisations by means of actuators and will be analysed to direct and dictate business processes. Hence, personalisation strategies should aim at contributing contextualised knowledge and insights that can support decision-making. Furthermore, the current definition and manifestation of personalisation as found in the literature and embedded in knowledge management strategies needs to be altered resulting from the design principles of a DNE. It is evident that big data and the management of the same by means of automated technologies and robotic process automation will characterise DNE's. However, the need for personalisation will become of far more prominence as data needs to be contextualised to become information and contribute to an increase in personal and organisational knowledge.

BACKGROUND

The NDE and specifically the extent and nature of work that is performed in the aforementioned requires a reconceptualisation of the relevance of Knowledge management and additionally the manner in which it should be practised. The applicability and relevancy of knowledge processes will be critically evaluated in an organisation where workers are seamlessly connected through ubiquitous technologies. In future, data will be generated by sensor-enabled technologies and analysed by powerful business analyses tools that will inform decision-making in the workplace and in society.

The business criticality of Knowledge management is considered in organisations and societies where workers are increasingly made redundant because of the physical and cognitive ability of machines to perform both repetitive but also highly complex work. The manner in which Knowledge management can contribute to business value is questioned in an age where thousands of devices are connected in the cloud and are able to perform both simple and complex tasks without any or with only limited interaction with their human counterparts.

Reflecting on the applicability and relevancy of Knowledge management within the setting of a DNE is therefore necessary. Additionally, the Chapter deliberates the nature and scope of the deliverables of knowledge management capabilities as well as the required skillset of knowledge managers. The Chapter could also guide and inform the development of knowledge management curricula at institutions of higher education as it reflects on core skills that knowledge managers should obtain prior to entering the profession.

METHODOLOGY

Objective qualitative research was conducted to ascertain the nature and extent of the future of work in the setting of a 4IR organisation. Van Maanen (1979) states that qualitative research is "at best an umbrella term covering an array of interpretative techniques which seek to describe, decode, translate and otherwise come to terms with the meaning, not the frequency, of certain more or less naturally occurring phenomena in the social world." Furthermore, deductive inferences were used to draw conclusions on the manifestation of knowledge management in a 4IR organisation Johannson (2003) explains: "When a generalisation is based on the deductive principle, the procedure is similar to an experiment: a hypothesis is formulated, and testable consequences are derived by deduction. By comparing the expected findings, which are deduced from a theory and a case, with the empirical findings, it is possible to verify or falsify the theory. As a result, it is possible to define the domain within which the theory is valid more exactly. Cases that are pivotal to the theory are selected. The testing of the theory is comprised of the emulation of experimental method in a naturalistic setting. From a theory and the facts of a case, generalisations are drawn concerning the domain of the theory." Additionally, the study will have a dual approach, whereby non-empirical or conceptual research is combined with empirical research. The non-empirical component will include a literature study while the empirical component will entail that case studies are conducted. In order to collect data a literature study is conducted to contextualise the subject of the study in a theoretical framework. The significance of a literature study is apparent from the statement made by Mouton (2001): "A comprehensive and well-integrated literature review is essential to any study. It provides you with a good understanding of the issues and debates in the area that you are working in, current theoretical thinking and definitions, as well as previous studies and their results." The content of the literature review will be confirmed or refuted through a comparative analysis between the literature and actual manifestations or case studies of knowledge management in organisations with characteristics which reflect a 4IR organisation. Mouton (2001) confirms the necessity of a literature study but emphasises the importance of supporting the findings of the literature through empirical research: "Although literature reviews often lead to theoretical insights, we still need to undertake an empirical study to test our new insights." The empirical component will consist of descriptive case studies.

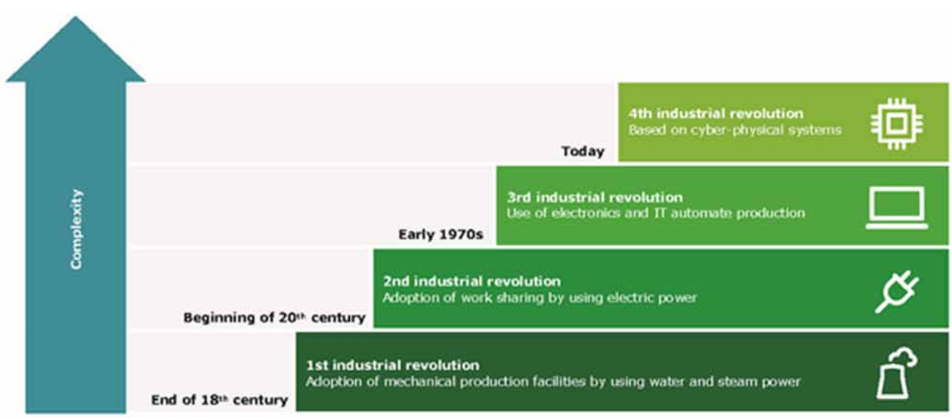
DIGITAL KNOWLEDGE MANAGEMENT CONSTRUCT

Fourth Industrial Revolution

Digital transformation is a direct result of the 4IR. The 4IR has emerged circa 2010 and is characterised by the introduction of CPSs in organisations as depicted in Figure 1.

In its most fundamental form, the 4IR is the seamless integration of disparate devices on the cloud. The integration of disparate devices enables the flow of big data that needs to be analysed and contextualised to influence sense and decision-making. Schwab (2016) describes the 4IR by stating that "Characterized by new technologies fusing the physical, digital and biological worlds, the Fourth Industrial Revolution will impact all disciplines, economies and industries – and it will do so at an unprecedented rate." He (Schwab, 2016) continues "Consider the unlimited possibilities of having billions of people connected by mobile devices, giving rise to unprecedented processing power, storage capabilities and knowledge access. Or think about the staggering confluence of emerging technology breakthroughs, covering wide-ranging fields such as artificial intelligence (AI), robotics, the internet of things, autonomous vehicles, 3D printing, nanotechnology, biotechnology, materials science,

Figure 1. Industrial Revolutions (Van Herreweghe, 2015)



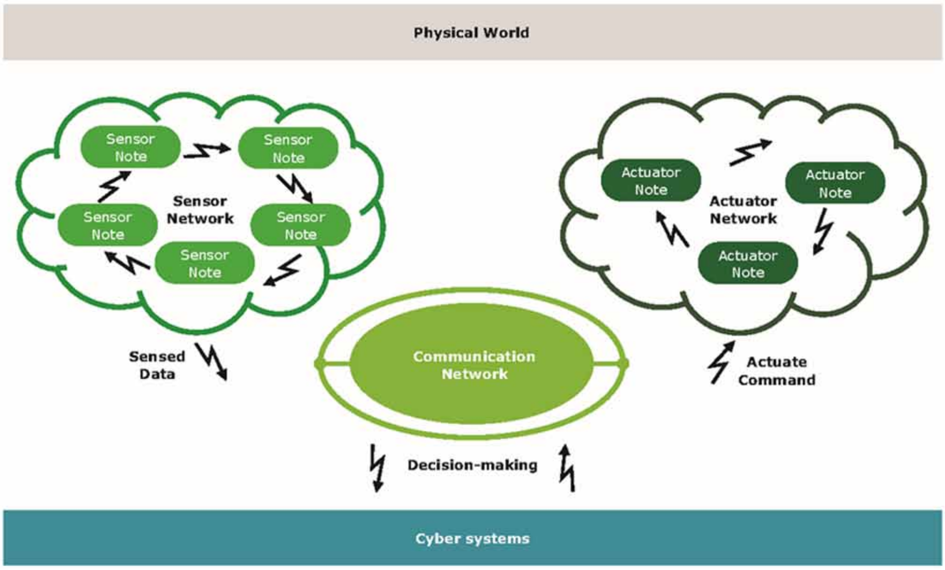
energy storage and quantum computing, to name a few." Colombo et al., (2017) concurs and states "Industrial Cyberphysical Systems are expected to empower the transformation of industry and business at large to a digital, adaptive, networked, and knowledge-based industry with significant long-term impact on the economy, society, environment, and citizens. In a more recent contribution Marr (Brar, 2018) explain that the 4IR represents exponential changes to the way we live, work and relate to one another due to the adoption of cyber-physical systems, the Internet of Things and the Internet of Systems. As we implement smart technologies in our factories and workplaces, connected machines will interact, visualise the entire production chain and make decisions autonomously."

Typical technologies that will result from the integration of physical and cyber systems within the 4IR are described by Schwab (2016):

- Implantable technologies in the form of mobile devices are increasingly becoming connected to the bodies of human. Devices are not just being worn, but also being implanted into bodies, serving communications, location and behaviour monitoring, and health functions
- Big data for decisions will allow for the first government to replace its census with big data sources
- Wearable internet and, increasingly, clothing and other equipment (like reading glasses) worn by people will have embedded chips that connect the article and the person wearing it to the internet
- Internet traffic in homes will be directed towards appliances allowing for home automation; enabling people to control lights, shades, ventilation, air conditioning, audio and video
- Tax will be collected for the first time by a government via a blockchain
- Large percentages of global gross domestic product stored on blockchain technology
- 3D printing and human health in the form of the first transplant of a 3D-printed liver
- Designer beings and the deliberate editing of human genomes

A CPS is characterised by the integration of computational and physical components and hence provide for computers to monitor and control physical work processes. Baheti and Gill (2011) defines CPSs as "a new generation of systems with integrated computational and physical capabilities that can interact with humans through many new modalities." Zanni (2015) describes the integration between sensors and actuators in a CPS in the following manner: "CPSs use sensors to connect all distributed intelligence in the environment to gain a deeper knowledge of the environment, which enables a more accurate actuation. In a physical context,

Figure 2. Holistic view of CPS (Gunes et al., 2014)



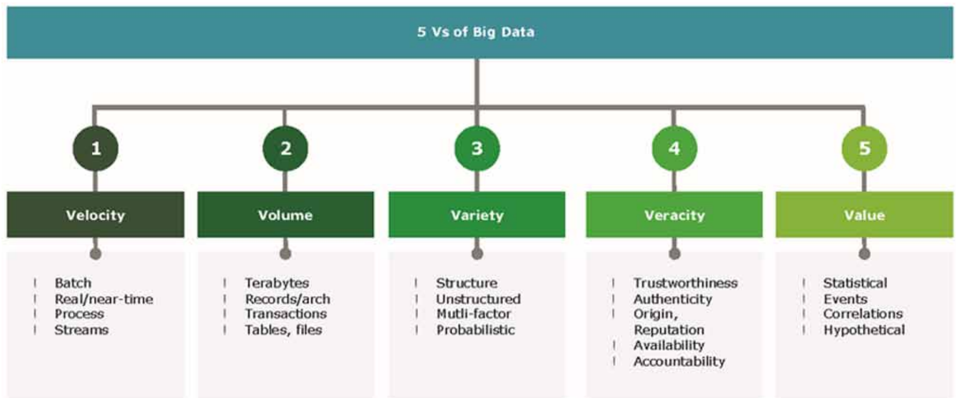
actuators act and modify the environment where users live. In a virtual context, CPSs are used to collect data from the virtual activities of users."

The integration between sensed data and actuated commands is depicted in Figure 2.

The ability of CPSs to control and monitor physical processes by means of behavioural sensor-enabled or "smart" technology have created a fundamental shift or a digital transformation in the way that work is conducted in DNEs. CPSs will improve technological and digital productivity but organisations need to revisit and if necessary adjust operational processes to ensure that they continue to create value for customers. Technological and digital productivity can create inefficiencies or waste if not characterised by "simplicity and agility" (Bhalla, Dyrcks & Strack, 2017). Digital technologies will only increase revenue, lower cost and add value to customers if these technologies are integrated in a well-sequenced way with the operating model of the organisation (De Smet, Lackey & Weiss, 2017). Küpper *et al.* (2017) reports on the necessity of integrating CPSs with lean production principles and indicate that such an approach can reduce costs related to poor quality by 20% and work-in-process inventory by 30%."

Colombo et al., (2017) describes the nature of the industrial environment or ecosystem in the following manner:

Figure 3. The five characteristics of big data (Ishwarappa & Anuradha, 2015)



- "The workforce is not only interacting with CPSs but also becoming an integral part; i.e., transforming into another CPS that, in turn, interacts over Internet technologies with the industrial cyber-physical system (ICPS) ecosystem.
- Subject matter experts transform into knowledge workers that analyse complex information at the right time in the right place and make decisions.
- Although the subject matter expert continues to be autonomous, via the CPS interaction, his capabilities and effectiveness are increased.
- The workforce now collaborates and offers its services, which can be requested by any other CPS (including other machines).

The aforementioned explicates the highly connected nature of the work environment and the seamless flow of information between the cyber and physical world.

Bhalla, Dyrcks and Strack (2017) state "Advanced analytics, in turn, makes it possible to analyse enormous amounts of unstructured data, improving forecasting and decision-making as never before." Additionally, Shaler-Shwartz and Ben-David (2104) indicate the importance of the "automated detection of meaningful patterns in data to enable machines to "learn". This illustrates that the term "continuous learning" will increasingly also be used to imply continuous learning by machines. Machine learning should also be based on experience and state that "we wish to program computers so that they can "learn" from input available to them. Roughly speaking, learning is the process of converting experience into expertise or knowledge" (Shaler-Shwartz & Ben-David, 2104). However, the availability of big data requires "mechanisms for capturing, cleaning, aggregating, and analysing data" to enable value-adding decision-making in organisations (Bhalla, Dyrcks & Strack, 2017). Nagle, Redman and Sammon (2017) are of the opinion that: "Bad data wastes time, increases costs, weakens decision-making, angers customers, and makes it more difficult to execute any sort of data strategy." The aforementioned emphasises the importance of managing the five characteristics of big data as depicted in Figure 3.

The Digital Native Enterprise

The DNE will be fundamentally different from current manifestations of organisations. Essentially, the changes will be visible through pervasive digital transformation driving an increase in technological and digital productivity and an altered state of thinking regarding generating value.

- Technological and digital productivity due to the incorporation of automation, big data and advanced analytics as well as access to information and ideas.
- Shifts in ways of generating business value due to simplicity in [organisational processes and procedures, agility and innovation in an effort to attract and retain clients.

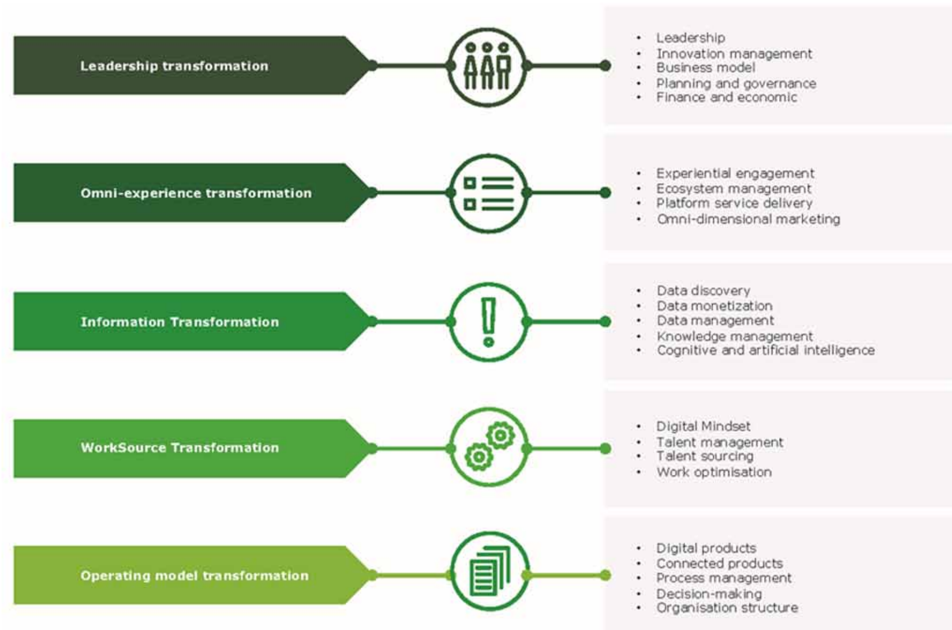
Rosen et al. (2017) describes the impetus for the DNEs by stating that: "Digital transformation has progressed to where it is now an existential concern for many enterprises. Growing organisations strive to become "digital native" in the way they think, what they produce, and how they operate. Yet many organisations have difficulty in imagining what the new digital future could be."

DNE's differentiates itself from other enterprises in the manner in which data is optimised to serve clients in a novel way. The differentiating factor is the way in which data as opposed to knowledge become the primary commodity. The responsibility and requirement is for DNEs to ensure that data displays the necessary characteristics in order for it to be integrated into systems and enable commercial transactions and interactions. Rosen et al. (2017) explains that "a DNE creates and delivers innovation at speed. Clients are at the core of its existence. Employees are its assets. Technology and data are its lifeblood. Ecosystem is its ally."

To this end the design principles of a DNE can be described as:

- Data as the catalyst for processes: Data and the utilisation thereof is core to success. Cognitive and artificial intelligence technologies and information drive improved engagement, new products, optimised operations, and enhanced decision-making (Rosen et al., 2017)
- Consumer engagement and scale are mandatory: Whether your enterprise touches consumers directly or indirectly, competing increasingly requires connecting value to consumers, their homes, and lifestyle (Rosen et al., 2017)

Figure 4. Five dimensions of DNE effectiveness (Rosen et al., 2017)



- Ecosystems are as important as knowledge: Maximise leverage through communities – developers, partners, and customers around industry collaborative platforms will determine much of the DNE success.” (Bhalla, Dyrcks & Strack, 2017; Rosen et al., 2017).

Rosen et al. (2017) continues by suggesting a model of the five dimensions of DNE effectiveness and identifies the core components that need to be present for sustainability.

From the deliberation on the design principles of a DNE is evident that a new state of skilfulness and mindfulness will be required by workers in the 4IR.

Cognitive Augmentation and Human Skills

It is evident that the analysis of big data will enable the automation of repetitive tasks like assembling parts in a factory, and in addition to complex tasks that have traditionally been the domain of humans. Mortensen (2017) indicates that the role of machines is not to replace humans but merely for humans and machines to work alongside humans. Humans are thus enabled to perform tasks that machines cannot learn or automated. This co-existence with machines would necessitate humans to develop or strengthen skills that cannot be transferred to machines by means of machine learning, cognitive computing and eventually artificial intelligence (AI). Essentially, a DNE would be characterised with an ecosystem in which the "knowledge" or big data "fed" to machines will need to be managed while the non-replicable skills of humans would need to be optimised.

The nature of the co-existence between machines and humans has been an ongoing discourse and have given rise to various schools of thought on the juxtaposition between man and machine. Already in 1968, Martin Luther King presented a sermon on "*Remaining Awake Through a Great Revolution"* and stated: "There can be no gainsaying of the fact that a great revolution is taking place in the world today. In a sense it is a triple revolution, with the impact of automation and cybernation; then there is a revolution in weaponry, with the emergence of atomic and nuclear weapons of warfare; then there is a human rights revolution, with the freedom explosion that is taking place all over the world. Yes, we do live in a period where changes are taking place." (Ford, 2015). Mortensen (2017) concurs: "the debate between artificial intelligence (machines replace us) versus intelligence augmentation (machines help us) has been raging for decades. One side wants to engineer humans out of the equation, while the other thinks the role of machines is to help people perform better." Clarification is needed on the nature and extent of the "new" roles for humans within Fourth Industrial Revolution organisations."

It is evident that the inherent nature of the various dimensions of the DNE will require new competencies and capabilities of workers. The cognitive ability of workers will be augmented with intelligent and automated systems, processes and procedures.

The World Economic Forum (2016) divides the drivers of change that will necessitate workers to develop and enhance their existing skillsets in order to prepare for and accommodate a new world of work in two categories. These two categories are demographic and socio-economic change. The World Economic Forum (2016) states: "Developments in previously disjointed fields such as artificial intelligence and machine learning, robotics, nanotechnology, 3D printing and genetics and biotechnology are all building on and amplifying one another. Smart systems – homes, factories, farms, grids or entire cities – will help tackle problems ranging from supply chain management to climate change. Concurrent to this technological revolution are a set of broader socio-economic, geopolitical and demographic developments, each interacting in multiple directions and intensifying each another. While these impending changes hold great promise for future prosperity and job creation, many of them also pose major challenges requiring proactive adaptation by corporations, governments, societies and individuals."

The World Economic Forum (2016) describes the nature of changes influencing the manifestation of work in a DNE as follows:

Demographic and socio-economic:

- Changing nature of work environments and flexible working arrangements.
- Rise of the middle class or the so-called economic centre of gravity is shifting towards emerging markets.
- Climate change, natural resource constraints and the transition to a greener economy.
- Rising geopolitical volatility with an impact on global trade and talent mobility.
- New consumer concerns about ethical and privacy issues.
- Longevity and ageing societies and the resultant need for new products, services and business models.
- Young demographics in emerging markets and the resultant need for education and training systems.
- Women's rising aspirations and global economic power.
- Rapid urbanisation with a projected increase of double the current world population between 2010 and 2050 from 2.6 billion to 5.2 billion.

Technological:

- Mobile internet and cloud technology enabling more efficient delivery of services and opportunities.
- Advances in computing power and big data.
- New energy supplies and technologies
- The Internet of Things
- Crowdsourcing
- The sharing economy and peer-to-peer platforms
- Advanced robotics and autonomous transport
- Artificial intelligence and machine learning.
- Advanced manufacturing and 3D printing.

Knickrehm (2018) explains that it is "critical for companies to understand the range of opinions on this issue because implicitly or explicitly, they will influence the way business leaders create the workplace of the future."

Five schools of thought shape discussions and decisions in respect of the future world of work and specifically the debate between the positioning of AI vis-à-vis humans.

- **Dystopian View:** The dystopian view describes a scenario in which "man and machine will wage a Darwinian struggle that machines will win. AI systems will take on tasks at the heart of middle- and high-skill jobs, while robots will perform menial work that requires low-skill labour." The effect will be considerable levels of unemployment with resultant economic and socio-economic effects."

- **Utopian View:** Machines will be responsible for work however positive synergy will exist between man and machine. This synergy will enable productivity and lead to economic growth. In this scenario: "Human brains will be "scanned" and "downloaded" to computers and billions of replicated brains will do most of the cognitive work, while robots will do all the heavy lifting."
- **Technology Optimist View:** Technology optimists have embraced intelligent technologies and a "burst of productivity" has begun. AI is perceived as positive since it can create economic growth and improvements in living standards but would require an "investment in education and training alongside investments in technology."
- **Productivity Sceptic View:** AI will not be able to achieve the perceived productivity gains. Together with global challenges such as "aging populations, income inequality, and the costs of dealing with climate change" it will not succeed in make a fundamental difference to economic growth.
- **Optimistic Realist View:** AI can enable productivity that equals previous technology and replicate previous trends where demand rose for both high- and low-skill workers whose jobs could easily be automated, while demand for middle-skill workers fell." (Knickrehm, 2018).

It is therefore evident that the design principles of the DNE and the resultant co-existence between humans and machines necessitate a reconsidered skilfulness.

Mortensen (2017) therefore confirms the view of the World Economic Forum (Gray, 2015) as it relates to the importance of the following skills that will be prominent in a 4IR organisation: complex problem solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence, judgement and decision-making, service orientation, negotiation and cognitive flexibility. Mortensen (2017) states: "One implication for all of this is that for humans to succeed in the Artificial Intelligence-powered future, we need to double down on our humanity. Technical skills will no doubt remain important in the future of work, but as AI allows us to automate repetitive tasks across many industries, these will in many cases take a back seat to soft skills. Communication, emotional intelligence, creativity, critical thinking, collaboration, and cognitive flexibility will become the most sought-after abilities. To prepare for that future, we need to emphasize developing higher-order thinking and emotional skills." Furthermore, Mortensen (2017) explains: "One implication for all of this is that for humans to succeed in the Artificial Intelligence-powered future, we need to double down on our humanity. Technical skills will no doubt remain important in the future of work, but as AI allows us to automate repetitive tasks across many industries, these will in many cases take a back seat to soft skills. Communication, emotional intelligence, creativity, critical thinking, collaboration, and cognitive flexibility will become the most sought-after abilities. To prepare for that future, we need to emphasise developing higher-order thinking and emotional skills." Mortensen's views (2017) is largely confirmed by Gustein and Sviokla (2018) when indicating seven core skills that will ensure employability in a DNE.

These skills are:

- **Communication:** The ability to engage and to deliver a message in a compelling manner.
- **Content:** The ability to understand a specific topic combined with the ability to be innovative and to provide eminence or thought leadership in the same topic.
- **Context:** The ability to have a contextual understanding or understand the dynamics of a specific situation or event, interaction or engagement.
- **Emotional competence:** The ability to:

o Recognise the emotions at play in the context of analysis and action

o Successfully intervene in an emotionally complex situation

o Persuading individuals and groups by evoking emotion

- **Teaching:** The ability to teach and train others by having a highly contextualised understanding of the environment where skills and knowledge need to be applied.
- **Connections:** The ability to create strong professional ties and in addition develop a large network of weak ties. Additionally, it is also necessary to develop a network of weak ties in a variety of professional domains.
- **Ethics:** The ability or capacity for moral judgement. Gustein and Sviokla (2108) describe the value of moral judgement in a DNE and states: "However, the essence of moral judgement is that there is no easy algorithm to maximize "value", so systems that rely on algorithms are inadequate in situations involving judgments."

The seven core skills that will ensure skilfulness in the 4IR are also iterated by Curtin (2018) when stating that employability is enhanced by: "Cognitive flexibility; Negotiation skills; Service orientation; Judgement and decision-making; Emotional intelligence; Coordinating with others; People management; Creativity; Critical thinking; Complex problem-solving.

It is therefore evident that in addition to the ability to master "technical" skills there will be an increased focus in the DNA on capabilities and competencies that surpasses the scientific, technical, engineering and mathematical level.

KNOWLEDGE MANAGEMENT

DNEs necessitate a repositioning of Knowledge management in an age where humans are seamlessly connected through ubiquitous technologies. What will the role of KM be in organisations and societies where humans will become redundant because of the ability of machines to perform both repetitive but also highly complex work?

Pushpa (2109) deliberates the question "what exactly does organizations do with knowledge" in an effort to develop insights into the manner in which Knowledge management should be repositioned. Pushpa (2109) explains "Organizations perform different kinds of tasks, and their success and competitiveness depends on their maturity in performing critical tasks, as well as where they stand with respect to industry in this. Tasks are performed by employees and machines, who take input information about the task, process the same based on knowledge (know-how and know-why) and complete the task". Pushpa (2019) continues by stating that "in the case of humans, they can process large variation in the input information with respect to a task, even if the input information is not clear, they can remove the noise and if they do not have the relevant knowledge to process the information, they do further study, discuss with others, gain further knowledge and work on the information." It is evident that humans contribute know-what (procedural knowledge), know-why (causal knowledge) as well as highly contextualised and strategic know-how. Venkitachalam and Willmot (2017) explains the importance of strategic know-how when stating that "Knowledge strategies involve the use of different types of know-how linked to the operation of business processes that are orientated towards the improvement of competitiveness. Such know-how includes knowledge of suppliers, customer knowledge, employee knowledge, competitor intelligence, industry knowledge, firm innovation through exploration and exploitation of organisational knowledge capabilities and so on."

Knowledge management is the scientific discipline that aims at managing information (explicit knowledge) and knowledge (tacit knowledge) to ensure a competitive advantage for the organisation. Janus (2016) contributes a further "form"

Figure 5. Knowledge processes (APQC, 2018)

of knowledge when stating that knowledge can also be implicit or experiential. Implicit knowledge is intangible and can be converted to a tangible or explicit form.

Davenport and Prusak (Dalkir, 2005) describes the requirement of organisations in respect of Knowledge management and states: "Increasingly companies will differentiate themselves on the basis of what they know. An organisation that knows how to do things would define a business firm that thrives over the next decade as an organisation that knows how to do new things well and quickly." The proliferation of information and knowledge have placed an additional requirement on Knowledge management in the sense that companies do not only differentiate themselves on "what they know" but also on their ability to effective identify and make knowledge assets available and accessible.

There are various definitions of Knowledge management but in its most fundamental manifestation it is "the deliberate and systematic coordination of an organisation's people, technology, processes, and organisational structure in order to add business value through the reuse of knowledge. Recently, it has become evident that Knowledge management is also an enabler of governance principles and it often facilitates compliancy to management systems and practices. This is achieved through the promotion of creating, sharing, and applying knowledge as well as through the feeding of valuable lessons learned and best practices into corporate memory in order to foster continued organizational learning." (Dalkir, 2005). The American Productivity and Quality Centre (APQC) (2018) adds four more knowledge processes as an extension to Dalkir's (2005) rather limited view of the full knowledge process value chain. End-to-end or the full knowledge processes value chain includes creating, identifying, collecting, sharing, accessing and using or applying knowledge.

Furthermore, Knowledge management is characterised by a people, process and a supporting technology or methodology component.

The APQC (2018) alludes to the necessity of a clearly defined and articulated knowledge management strategy to guide and inform organisational Knowledge management efforts. They state (2018): “Whether an organization is starting a new Knowledge management effort or evaluating an existing program, it is crucial to have a documented Knowledge management strategy. A clearly-articulated strategy provided alignment and credibility to the work of the Knowledge management team, helps secure stakeholder buy-in, and keeps the Knowledge management group focused on business-relevant goals.”

Knowledge management strategies are focused on codification and personalisation and it is evident that the organisations that derive the most competitive and sustainable value from Knowledge management are those that have a balanced approach towards codification and personalisation (Hansen, Nohria & Tierney, 1999; Van der Spek, Hofer-Alfeis & Kingma, 2003; Venkitachalam & Willmott, 2017). Codification focuses on codifying and capturing knowledge in the form of information in databases while a personalisation strategy enables communication and person-to-person or person-to-team dialogues as opposed to codifying and capturing knowledge objects in a database. Personalisation ensures that the tacit knowledge (experiences, narratives, stories, heuristics, mental models, values) of employees can be leveraged in teams and between teams and hence make provision for highly contextual knowledge.

The majority of organisational Knowledge management initiatives are biased towards a technological approach and hence support a codification strategy. Organisations should guard against an overemphasis on a technology driven and in some instances a compliancy driven approach towards knowledge management. The quantity and frequency of knowledge management processes should neither dominate nor dictate the quality and value of the same. This implies that a focus on how “much and how often” knowledge is shared should not be more important than the value and practicality of the contextualised knowledge that is shared. Natarajan (2018) explains: “While Knowledge management practises and tools achieved considerable success across industries more specifically in knowledge driven industries such as Consulting, IT, legal, pharma, life sciences, etc. they are mostly focused on codifying explicit knowledge artefacts and providing search and retrieve capabilities to discover the artefacts from the repository.”

As “knowledge” in the form of data will be embedded in seamlessly interconnected devices, equipment and machines it is evident that the existing relationship between codification and personalisation knowledge management strategies will need to be reconfigured and aligned with the digital “maturity” of the organisation.

It is generally accepted that in a DNE "knowledge" will be in the form of "big data" that is received by sensors and transmitted to actuators and which can be analysed in a cloud-based CPS. The analyses of big data sets will enable the seamless integration of the products developed and services delivered by organisations and society. All with relatively little intervention from humans and a low dependency on their ability to apply their acquired knowledge and experience to perform knowledge work or physical labour. However, it is noteworthy that although Knowledge management has traditionally focused on managing information and tacit knowledge as organisational resources and excluded the domain of data management. In the DNE the fusion and integration between data, information and knowledge is unmistakable.

Natarajan (2018) states "the key challenge for Fourth Industrial Revolution organizations is to harness the real potential for digital transformation by having an integrated strategy and a holistic approach towards knowledge management, building internal systems and processes to streamline information exchange and data analytics, along with a strong culture of data-driven decision-making."

This is also evident from the five dimension model of a DNE as proposed by Rosen et al. (2017). This model clearly indicates the necessity of including Knowledge management in a DNE but also emphasise the need for a "transformed" manifestation of "knowledge". In a DNE Knowledge management needs to embrace the following:

- Knowledge that is hidden in limitless data that can be unlocked, processed, and eventually embedded in products, services, or systems (Rosen et al., 2017)
- An absence of barriers and boundaries to accelerate the flow, development, and sharing of knowledge." (Rosen et al., 2017)
- Large volumes of structured and unstructured data across organisational value chains
- The inclusion of sensors as the conduit of data as opposed to the human worker as the "owner" of intellectual property in the form of knowledge and information
- The incorporation of an ecosystem of advanced technologies (cognitive search; enhanced discovery and predictive recommendations; chatbots and intelligent assistants) to enable the automation of routine knowledge processing and analysis (APQC, 2018).

Pushpa (2019) confirms the role of Knowledge workers in a DNE when contextualising the benefits and limitations of AI in a DNE. He states that AI will contribute to the ability to identify and make knowledge assets available and accessible hence contributing to the findability of assets. However, AI "cannot leverage existing knowledge: This is another great drawback of AI. AI is data driven and creates insights from data to improve. It is not able to leverage knowledge generated from other sources, bring them together and create a new know-how with respect to the task it is performing." It is therefore evident that Knowledge management will remain relevant in respect of creating an environment in which contextualised and strategic know-how is managed.

ANALYSING KNOWLEDGE MANAGEMENT IN A DIGITAL NATIVE ENTERPRISE

Three settings, which are representative of a typical DNE setting, are included in the research. These settings were specifically chosen to examine the dynamics between the dominant two types (personalisation and codification) of knowledge management strategies. Furthermore, the chosen settings facilitate the identification of "typical" work that needs to be performed in a DNE. Subsequently, each setting is analysed in terms of the type of knowledge management strategy that it supports, the individuals responsible for knowledge management activities, the dominant knowledge process(es) and technology or methodology that are utilised as well as an indication of the project lifecycle which is supported by the knowledge management activities. The cases were a Smart City (Case A), an intelligent mine (Case B) and a typical AI environment (Case C).

Case A: Smart City

Steinmetz (2018) described the contribution of knowledge management to transform Tel Aviv into a smart city. Smart cities "are smart (thoughtful, people-centric), digital (driven by data acquisition, measured, analysed and sometimes exchanged) and virtual (experiential). And, as a result, they are connected, creating more potential interactions between people and their place." The City of Tel Aviv is using focus groups and unique knowledge management processes to feed municipal data into the DigiTel platform. DigiTel cardholders have access to the DigiTel platform, which is a personalised web, and mobile platform that provides residents with individually tailored, location-specific services delivered via email, text messages and personal resident accounts." According to the Chief Knowledge Officer of Tel Aviv "daily updates inform residents about road closures in their area, registering for school, local events, development or heritage conservation proposals requiring feedback, community greening initiatives, recycling, and invitations to public surveys are contained in the DigiTel platform. Furthermore, it gives residents access to discounted rentals of beach equipment, theatre and movie tickets, car-share rentals, and a variety of other services. The DigiTel platform enables two-way communication between the users of the platform and the municipality of Tel Aviv. Users tell the municipality what is happening in their area. They can give back information about, for example, broken city signage or playground fixtures needing attention. The municipality sees the community members as having “wisdom”: they are the most informed about what is happening in their local area.”

The case study portrays the importance of contextualised knowledge in a hyper-connected Smart City environment and hence is indicative of the continued relevancy of Knowledge management in a DNE.

Strategy

A codification strategy was followed since information about the municipal services in Tel Aviv is captured in the DigiTel platform. The codification and capturing of data regarding municipal and related services ensures that residents are informed about services, infrastructure and the community in which the city is located. This results in an increase in productivity for residents (Venchitachalam & Willmott, 2016). Knowledge managers and champions are responsible for making data accessible to residents and should eventually also become involved in the analysis of the data to ensure optimisation of services and infrastructure, better decision-making and an increase in revenue for the municipality as improvements in service delivery is related to cost savings. The codification strategy is enhanced with contextualised knowledge and additionally connect people to personalised content.

Process

The knowledge processes of codifying, capturing, organising, sharing and the application of information or explicit knowledge are enabled by the DigiTel platform. However, the sustainability of the DigiTel platform is dependent on the evaluation and validation and hence the personalisation of the information contained in the system.

People

The codification and the capturing of the information is the responsibility of the “knowledge champions”. The task of codifying and capturing data could potentially be replaced by sensor-enabled equipment and technology, which would monitor and report on the availability and condition of infrastructure in the municipality. However, it is evident that information contained within the platform makes provision for a level of customisation as it includes content on the manner in which residents perceive and experience municipal services. The ability of the platform to include content, which relates to the perceptions and feelings of the residents are a determining factor in the continued utilisation of the platform as a sensor would not be able to capture and codify and analyse subjective and personal perceptions and feelings.

Technology/Methodology

The codification strategy was enabled by a technology platform.

Project Life-Cycle

The codification and capturing of the information in the DigiTel Platform activated the smart city initiative as the application and utilisation of the platform was dependent on the codification and capturing of the information in the platform.

Natarajan (2018) explains the manner in which codified and captured knowledge could be further enhanced by adding a layer of artificial intelligence and machine learning to a database such as the DigiTel platform. This would give effect to the need for contextualised or personalised knowledge in a DNE. Natarajan, 2018) explains "Essentially, artificial intelligence/machine learning and KM are two sides of the same coin. An advanced KM platform with a built-in AI engine can bring contextual knowledge and predictive models for a business problem and help practitioners discover effective solutions faster." This statement by Natarajan (2018) confirms Pushpa's (2019) view that AI will contribute to "Knowledge findability and Employee productivity: One of the most popular use cases with AI has been the ability to find relevant content faster. AI can improve searches drastically and give employees the information and the knowledge most relevant to them. This in turn will improve employee productivity and overall productivity."

Case B: Intelligent Mine

Data analytics were utilised to improve productivity and the availability of mining equipment at a North American open-pit mine. This resulted in substantial cost savings due to improved productivity and availability of the equipment. Durrant-Whyte et al. (2105) explains: "Historically, the mine had been achieving an average maintenance performance, running a maintenance schedule based on the equipment manufacturers' recommendations and on simple metrics such as mean time between failures. Nevertheless, it was still running into equipment failures that caused shortfalls on production targets and incurred expensive overtime charges from the maintenance teams, while at the same time falling commodity prices were forcing cuts in the mine's operating budget. By applying advanced analytics techniques, the mine was able to transform its maintenance approach through two initiatives, both based on analysis of the large quantities of data. The mine is now working on automatically incorporating inputs generated by advanced analytics into its maintenance processes."

Strategy

A codification strategy was followed since the improvements resulted from the analysis of large quantities of data.

Process

The mine captured large quantities of data within a system. On completion of the aforementioned process, the data was organised to enable advanced analytics and applied or utilised to enable production improvements. The data became information when captured in the system. Although substantial improvements have been made in terms of equipment maintenance and management Klein (1999) indicates that decision-making can be optimised when combining data analytics with the experiences, narratives and mental models of experienced individuals. Information becomes insights when data is codified and captured in a system and analysed. Matzler, Bailom and Mooradian (2007) concur and explain the necessity of incorporating the tacit knowledge of individuals in decision-making and explain that decision-making based on experience is a "highly complex and highly developed form of reasoning that is based on years of experience and learning, and on facts, patterns, concepts, procedures and abstractions stored in one's head." Knowledge transfer and specifically the leveraging of technical knowledge could potentially have made a further contribution to the production improvements and could have enabled even more savings. Trees (2015) states that "augmented cognition – human cognition augmented by computers and smart technology will accelerate as a trend affecting the KM profession over the next three years and will continue to change how people and organizations incorporate technology into the decision-making process."

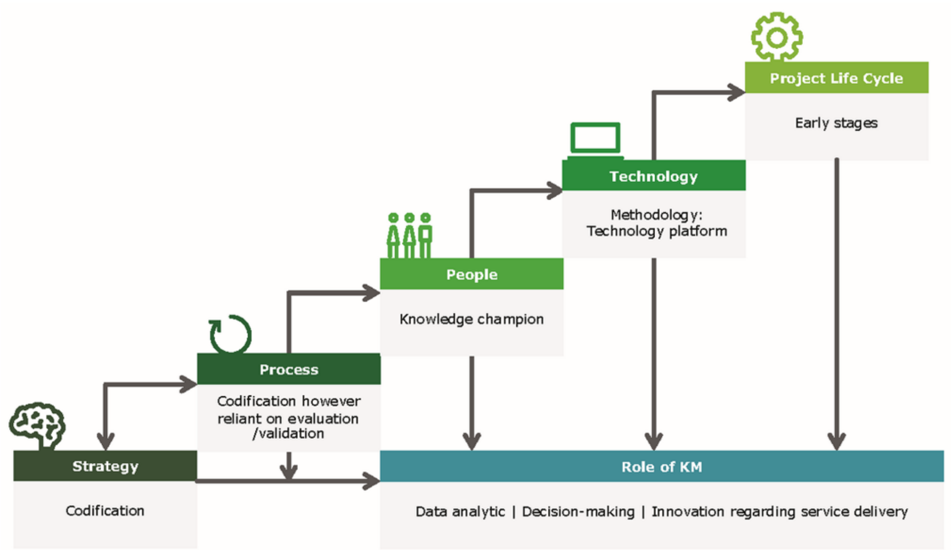
People

The case study does not report on the involvement of individuals in knowledge management roles in the process of codifying and capturing the data. Embedded sensors transmitted the data.

Technology/Methodology

The codification strategy was enabled by means of the data that are codified and captured in a system and which support advanced data analytics. However, facilitated knowledge

Figure 6. Smart mining KM process



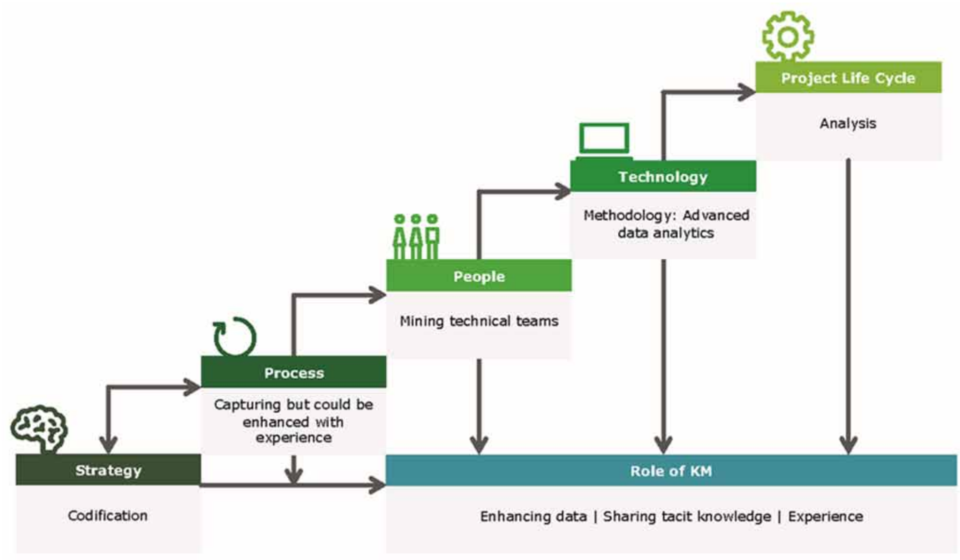
sharing and transfer sessions could have supported the analytics of the data and improved decision-making processes relating to the maintenance and management of equipment.

Project Life-Cycle

The analysis of the data is dependent on the codification and capturing of the same in a system. However, the decision-making process could be enhanced by comparing the results of the analysed data with the tacit knowledge of workers involved in equipment maintenance and management. This would ensure that decision-making is supported by contextualised tacit knowledge.

Rosen et al. (2017) confirms the importance of data as a precursor to decision-making and observes, "knowledge is hidden in limitless data that can be unlocked, processed, and eventually embedded in products, services, or systems. DNE's enterprise intelligence vision leads to a focus on comprehensive awareness, augmentation of the human decision maker, and automation of machine decision making." Pushpa (2019) confirms the view of Rosen et al. (2017) when stating that the DNE will be reliant on data to be successful. However, Pushpa (2019) confirms that the availability of data would need to be enhanced with contextualised knowledge to elevate it to know-how. He (2019) states "AI cannot leverage existing knowledge. This is another great drawback of AI. AI is data driven and creates insights from data to improve. It is not able to leverage knowledge generated from other sources, bring

Figure 7. Smart mining KM Process



them together and create a new know-how with respect to the task it is performing." Evidently, AI will need to be augmented by humans and hence require an intervention from knowledge managers to ensure that "contextualised" know-how is created.

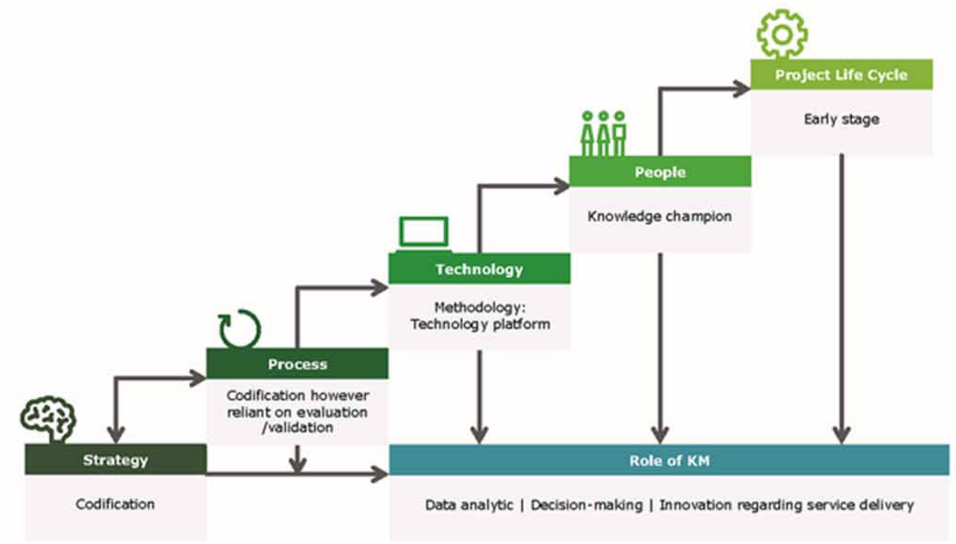
Case C: Contextualising Knowledge

Davies, Fidler and Gorbis (2011) explains the shortcomings of robots and machine learning as observed by IBM's supercomputer known as Deep Blue. Deep Blue defeated chess grandmaster Gary Kasparov and hence it was perceived that Deep Blue has superior thinking skills. Davies, Fidler and Gorbis (2011) explains that "Deep Blue had won with brute number-crunching force (its ability to evaluate millions of possible moves per second), not by applying the kind of human intelligence that helps us to live our lives. A computer may be able to beat a human in a game of chess by sheer force of its computational abilities, but if you ask it whether it wants to play pool, it won't be able to tell whether you are talking about swimming, financial portfolios, or billiards."

Strategy

Machine learning is almost completely based on a codification strategy. Data is analysed by means of "brute number-crunching force". There is no evidence of

Figure 8. Contextualising knowledge



the sharing of contextualised knowledge and hence a personalisation strategy as it relates to knowledge management.

Process

Machine learning is the ability for computers to learn and act without being explicitly programmed. However, in the use case learning is not contextualised and hence Deep Blue would not be able to apply "knowledge" in a different context. The use of machines is therefore limited in terms of sharing or transferring knowledge between projects with different variables. The robot or machine would need to be provided with a certain set of variables within which it would be able to apply learning.

People

There is no evidence of the involvement of knowledge workers in machine learning as it relates to the case study. It is challenging to identify the role of the knowledge worker in a machine-learning environment, as the inability to contextualise knowledge has always been the domain of knowledge management. Hence, the opportunity for knowledge workers to work alongside and collaborate with machines necessitates further research. The aforementioned is confirmed by Adams (2017) when stating that machines can learn, predict and understand natural-language questions and requests without the necessity of facilitated knowledge sharing interventions.

Technology/Methodology

Machine learning is based on mathematical models and algorithms.

Project Life Cycle

The interaction between knowledge management and machine learning within the context of the project life-cycle needs more research and remains a topic that necessitates further research.

Knowledge remains highly contextualised hence, knowledge managers would need to work alongside individuals responsible for creating mathematical models and algorithms.

The three use cases clearly indicate that the codification and capturing of big data and the subsequent analyses thereof would not necessarily create knowledge in the form of know-how in addition to decision-making. Insights will be created once AI and ML have been added to information codified and captured in systems and contextualised by means of personalisation. These insights enhanced with tacit knowledge will enable effective and informed sense and decision-making.

SOLUTIONS AND RECOMMENDATIONS

It is evident that "knowledge" and the ecosystem in which work is performed will differ radically between traditional organisations and digitally transformed organisations in the form of DNE's. DNEs will be characterised by the limitless influx of data and information as "DNEs have removed barriers and boundaries to accelerate the flow, development, and sharing of knowledge." (Rosen et al., 2017). Hence, the need for just-in-time or highly contextualised and validated knowledge will become increasingly relevant in a DNE. The aforementioned emphasises the importance of personalisation strategies. Personalisation strategies aim at the exchange of insights, opinions, experiences and expertise between users, employers, customers and suppliers. The aforementioned knowledge assets are non-replicable and hence affects the sustainability of the organisation. However, Natarajan (2018) is of the opinion that personalisation strategies should be supplemented with knowledge management systems enabled with cognitive engines that can gather meaningful insights and contextual knowledge. Natarajan (2018) explains: "An advanced Knowledge management platform with a built-in artificial intelligence engine can bring contextual knowledge and predictive models for a business problem can help practitioners discover effective solutions faster."

The altered state of KM in a DNE will require Knowledge workers to have the ability to:

- Assist in contextualising big data into insights in an effort to facilitate effective decision-making
- Identifying and "contracting" sources of knowledge or crowd resourcing
- Localising global knowledge
- Creating central employee-centric knowledge hubs
- Sourcing of relevant data and ensuring that data verified and clean prior to analyses
- Ascertaining the relevancy and the value of capturing and sharing experience
- Social innovation and sustainability of knowledge
- Social networks and empowering the global employee
- Ensuring that devices are connected to the Internet of Things and that knowledge can be created from the connectedness of devices
- Ensuring the safety and privacy of employees
- Ensuring system simplicity and hence limiting complicatedness in knowledge flows

Essentially, KM in a DNE will be characterised by the proliferation of data that will have a radical impact on primarily two knowledge processes (sharing, validation) and has additionally created the need for a further knowledge process (contextualisation).

FUTURE RESEARCH DIRECTION

The findings from the literature review in addition to the analysis of the three use cases clearly indicate the changing landscape of KM in a DNE. However, it is evident that many existing knowledge management capabilities will need to be reviewed and altered to remain aligned with business strategies that are increasingly transformed from a digital perspective.

O'Dell (2018) states "But many Knowledge management programs are still grappling with their role in digital transformation and how to change their processes in light of technological developments." O'Dell (2018) explains there are primarily four drivers that are accelerating the pace of change in Knowledge management. These four drivers are:

- Enterprise digital transformation initiatives
- The rise of robotic process automation

- Mass migration of enterprise systems to the cloud (where software is hosted on a vendor's servers and accessed through the web)
- An increase in affordable technological options for experimentation

In addition to the need for repositioning Knowledge management in an increasingly digital environment it is evident that both codification and personalisation strategies should be recognisable in a DNE. The use cases indicated that data in a digital environment are strategically enhanced by adding a personalisation layer to data "entering" the DNE by means of the CPSs in a highly connected ecosystem Furthermore, Venkitachalam and Willmott (2017) cautions that a biased approach towards codification in a DNE could be detrimental to the innovation capacity of a DNE. This is because codification necessitates the organisation of knowledge assets while personalisation is aimed at the leveraging of highly contextualised knowledge. Venkitachalam and Willmott (2017) explains 'that overemphasised codification efforts can result in 'knowledge structuration' and in this process dilute the purpose, meaning and contextual relevance of knowledge work in such situations. We further suggest that such 'knowledge structuration' (i.e. extreme codification that can be considered as information end') can impede idea generation. Novel insights and radical innovation due to hyper controls and structures in the organisation. This could lead to so many ideas lost/knowledge leakages."

CONCLUSION

The world of work will change fundamentally within the DNE. CPSs will enable the seamless integration between humans-and-machines, machines-and-machines and machines-and-humans. Increasingly, work that was performed by workers will become the "responsibility" of machines. This does not only relate to manual and repetitive tasks but includes cognition and highly complex tasks. Data analysis will enable decision-making and will result in production improvements and hence also cost savings and increased revenue. Workers will need new skills.

This Chapter deliberates the relevance of knowledge management strategies aimed at codification and position that the same will be replaced by embedding sensors in equipment and related devices and hence the codification and capturing of information in systems will become irrelevant. In DNEs where machines will be seamlessly integrated with almost all operational and business processes, it is becoming evident that humans will have to develop and enhance skills that will enable them to co-exist with machines. Hence, the role of the knowledge worker will increasingly focus on personalisation and on sharing highly contextualised and validated knowledge or insights in an effort to support digital transformation.

REFERENCES

Adams, R. L. (2017). *10 Powerful examples of artificial intelligence in use today*. Retrieved from http://www.forbes.com/sites/robertadams/2017/01/10/10-powerful-examples-of-artificialintelligence-in-use-today/#39af9a7420de

American Productivity and Quality Centre. (2018). *APQC's Knowledge flow process framework*. Houston, TX: APQC.

Baheti, R., & Gill, H. (2011). Cyber-physical systems. In The impact of control technology: Part 3: Cross cutting research directions. New York: IEEE Control Systems Society.

Bhalla, V., Dyrchs, S., & Strack, R. (2017). *Twelve forces that will radically change how organizations work*. Retrieved from https://www.bcg.com/publications/2017/people-organization-strategy-twelve-forces-radically-change-organizations-work.aspx/

Brar, H. K. (2018). *The electrified third "data" rail: how data is powering the Fourth Industrial Revolution.* Retrieved from https://medium.com/predict/the-electrified-third-data-rail-how-data-is-powering-the-fourth-industrial-revolution-dfb60ba64403

Colombo, A. W., Stamatis, K., Okyay, K., Shi, Y., & Shen, Y. (2017). Industrial cyberphysical systems: A backbone of the Fourth Industrial Revolution. *IEEE IEM*, *11*(1), 1–10.

Curtin, M. (2018). *The top 10 skills that will land you high-paying jobs by 2020.* Retrievable from https://www.inc.com/melanie-curtin/the-10-top-skills-that-will-land-you-high-payingjobs-by-2020-according-to-world-economic-forum.html

Dalkir, K. (2005). *Knowledge management in theory and practice*. Burlington, MA: Elsevier Butterworth-Heinemann.

Davies, A., Fidler, D., & Gorbis, M. (2011). *Future work skills 2020*. Retrieved from http://www.iftf.org/uploads/media/SR-1382A_UPRI_future_work_skills_sm.pdf

De Smet, A., Lackey, G., & Weiss, L. M. (2017). *Untangling your organization's decision-making*. Retrieved from https://www.mckinsey.com/business-functions/organization/our-insights/untangling-your-organizations-decision-making

Durrant-Whyte, H., Geraghty, R., Pujol, F., & Sellschop, R. (2015). *How digital innovation can improve mining productivity*. Retrieved from http://www.mckinsey.com/industries/metalsand-mining/our-insights/how-digital-innovation-can-improve-mining-productivity

Ford, M. (2015). *The rise of the robots: technology and the threat of mass unemployment*. London: Oneworld Publications.

Gray, A. (2015). *The 10 skills you need to thrive in the Fourth Industrial Revolution*. Retrievable from https://www.weforum.org/agenda/2016/01/the-10-skills-you-need-to-thrive-in-thefourth-industrial-revolution

Gunes, V., Peter, S., Givargis, T., & Vahid, F. (2014). A survey on concepts, applications, and challenges in Cyber-Physical Systems. *Transactions on Internet and Information Systems (Seoul)*, *8*(12), 4242–4268.

Gustein, A. J., & Sviokla, J. (2018). *7 Skills that aren't to be automated*. Retrievable from https://hbr.org/2018/07/7-skills-that-arent-about-to-be-automated

Hansen, M. T., Nohria, H., & Tierney, T. (1999). What's your strategy for managing knowledge. *Harvard Business Review*, *77*(2), 106–116. PMID:10387767

Ishwarappa, K., & Anuradha, J. (2015). A brief introduction on big data 5Vs characteristics and Hadoop technology. *Procedia Computer Science*, *48*, 319–324. doi:10.1016/j.procs.2015.04.188

Janus, S. S. (2016). *Becoming a knowledge sharing-organization: a handbook for scaling up solutions through knowledge capturing and sharing*. Washington, DC: International Bank for Reconstruction and Development / The World Bank. doi:10.1596/978-1-4648-0943-9

Johansson, R. (2003). *Case study methodolog*y. Retrieved from http://www.psyking.net/htmlobj-3839/case_study_methodology-rolf_johansson_ver_2.pdf/

Klein, G. (1999). *Sources of power: how people make decisions*. Boston, MA: Massachusetts Institute of Technology.

Knickrehm, M. (2018). *How will AI change work: Here are five schools of thought*. Retrievable from https://hbr.org/2018/01/how-will-ai-change-work-here-are-5-schools-of-thought

Küpper, D., Heidemann, A., Ströhle, D., Spindelndreier, D., & Knizek, C. (2017). *When lean meets Industry 4.0: the next level of operational excellence.* Retrievable from https://www.bcg.com/publications/2017/lean-meets-industry-4.0.aspx

Matzler, K., Bailom, F., & Mooradian, T. A. (2007). Intuitive decision-making. *MIT Sloan Management Review*, *49*(2), 2–15.

Mortensen, D. (2017). *Automation may take our jobs – but it'll restore our humanity*. Retrievable from https://qz.com/1054034/automation-may-take-our-jobs-but-itll-restoreour-humanity

Mouton, J. (2001). *How to succeed in your master's and doctoral studies*. Pretoria: Van Schaik.

Nagle, T., Redman, T. C., & Sammon, D. (2017). *Only 3% of companies' data meets basic quality standards.* Retrievable from https://hbr.org/2017/09/only-3-of-companies-datameets-basic-quality-standards

Natarajan, G. (2018). *Knowledge management and big data.* New Delhi: Confederation of Indian Industry.

O'Dell, C. (2018). *How to future proof your KM effort: insights from APQC KM expert Carla O'Dell*. Houston, TX: APQC.

Pushpa, R. (2019). *Artificial intelligence and knowledge management: understanding how they are linked.* Retrieved from https://www.linkedin.com/pulse/artificial-intelligence-knowledge-management-how-linked-pushpa/

Rosen, M., Pucaciarelli, J.C., Findling, S., Hand, L., Segal, R., Anderson, C., … Kolding, M. (2017). *How the digital-native enterprise is winning the future, now*. Farmingham: IDC.

Schwab, K. (2016). *The fourth industrial revolution.* Cologne: World Economic Forum.

Shaler-Shwartz, S., & Ben-David, S. (2014). *Understanding machine learning*. Cambridge, MA: Cambridge University Press. doi:10.1017/CBO9781107298019

Steinmetz, C. (2018). *How does a city get to be 'smart? This is how Tel Aviv did it*. Retrieved from https://theconversation.com/how-does-a-city-get-to-be-smart-this-is-how-tel-avivdid-it-94898

Timperley, B. (2018). How soon are robots going to steal our jobs. *Business Report.*, *8*, 1–22.

Trees, L. (2015). *How technology will affect the future of Knowledge Management*. Retrieved from https://www.apqc.org/blog/how-technology-will-affect-future-knowledgemanagement

Van der Spek, R., Hofer-Alfeis, J., & Kingma, J. (2003). The Knowledge Strategy Process. In C. W. Holsapple (Ed.), *Handbook on Knowledge Management* (pp. 443–466). Berlin: International Handbooks on Information Systems. doi:10.1007/978-3-540-24748-7_20

Van Herreweghe, M. (2015). *The 4th Industrial Revolution: opportunity and imperative: evolution for some, revolution for others.* IDC Manufacturing Insights White paper.

Van Maanen, J. (1979). *Qualitative methodology*. Beverly Hills, CA: Sage Publications.

Venkitachalam, K., & Willmott, H. (2017). Strategic knowledge management: Insights and pitfalls. *International Journal of Information Management*, *37*(4), 313–316. doi:10.1016/j.ijinfomgt.2017.02.002

World Economic Forum. (2016). *The future of jobs: employment, skills and workforce strategy for the Fourth Industrial Revolution*. Cologny: WEF.

Zanni, A. (2015). *Cyber-physical systems and smart cities, IBM Big data and analytics.* Retrieved https://www.ibm.com/developerworks/library/ba-cyber-physical-systems-and-smart-cities-iot/

ADDITIONAL READING

Leistner, F. (2010). *Mastering organizational knowledge flow: how to make knowledge sharing work*. Hoboken, N.Y.: John Wiley & Sons.

Leonard, D., & Sensiper, S. (1998). The role of tacit knowledge in group innovation. *California Management Review*, *40*(3), 112–132. doi:10.2307/41165946

Maynard, A. (2015). Navigating the fourth industrial revolution. *Nature Nanotechnology*, *10*(12), 1005–1006. doi:10.1038/nnano.2015.286 PMID:26632281

Nonaka, I. (1994). A dynamic theory of organizational knowledge creation. *Organization Science*, *5*(1), 14–37. doi:10.1287/orsc.5.1.14

Nonaka, I., & Konno, N. (1998). The concept of Ba: Building a foundation for knowledge creation. *California Management Review*, *40*(3), 40–54. doi:10.2307/41165942

Nonaka, I., & Takeuchi, H. (1995). *The knowledge creating company: How Japanese companies create the dynamics of innovation*. New York: Oxford University Press.

O'Dell, C., & Leavitt, P. (2014). *The executives role in Knowledge Management*. Houston, Texas: APQC.

Palansky, P., Widl, E., & Elsheikh, A. (2014). Simulating cyber-physical energy systems: Challenges, tools and methods. *IEEE Transactions on Systems, Man, and Cybernetics. Systems*, *44*(3), 318–326. doi:10.1109/TSMCC.2013.2265739

Patterson, R., Fournier, L., Pierce, B., Winterbottom, M., & Tripp, L. (2009). *Modeling the dynamics of recognition-primed decision-making*. Retrieved from https://www.bcs.org/upload/pdf/ewic_ndm09_s1paper12.pdf

Sauter, V. L. (1999). Intuitive decision-making. *Communications of the ACM*, *42*(6), 106–115. doi:10.1145/303849.303869

Venkitachalam, K., & Willmott, H. (2015). Factors shaping organizational dynamics in strategic knowledge management. *Knowledge Management Research and Practice*, *13*(3), 344–359. doi:10.1057/kmrp.2013.54

KEY TERMS AND DEFINITIONS

Big Data: Data sets created by the convergence of various devices, equipment, and systems and that are too complex for traditional data processing software.

Codification: A knowledge management strategy aimed at capturing and organising knowledge in a database. The integration of the physical and technological environment. This environment is in most cases cloud based and it regulated, controlled, and monitored by computer-based algorithms.

Decision-Making: The process of identifying the best or preferred course of action.

Digital Native Enterprise: An organisation in which processes, transactions and interactions are largely technology-enabled.

Fourth Industrial Revolution: An economy characterized by digital transformation, digital disruption, and trends such as the internet of things, virtual reality, machine learning, and artificial intelligence.

Knowledge Management: The discipline concerned with creating an environment in which both the tacit and explicit knowledge of organizations can be managed. The aim of knowledge management is to increase productivity and support innovation.

Knowledge Management Processes: Knowledge management strategies focus on identifying, collecting, sharing, accessing, applying, and validating knowledge.

Personalization: A knowledge management strategy aimed at sharing and leveraging highly contextualized knowledge and insights that can support decision making.

Section 3

Responsible Management in the Fourth Industrial Revolution

Chapter 9
Ecological Crisis, Sociality, and the Digital (Self-)Management

York Ulrich Kautt
Justus-Liebig-University Giessen, Germany

ABSTRACT

Following various findings of empirical studies, there is no doubt that the ecological crisis has to be regarded as one of the most pressing problems of the present. The chapter first discusses the importance of individual action for the ecological transformation of society. A following sketch of the limitations of political and economic action shows that the self-management of modern subjects is indispensable for such a transformation. The next section discusses social reasons that prevent the development and implementation of new, pro-environmental types of practice. Finally, on the basis of this diagnosis, some recommendations are formulated for a (yet to be developed) creative management of self-management.

INTRODUCTION

Following various findings of empirical studies, there is no doubt that the ecological crisis has to be regarded as one of the most pressing problems of the contemporary society. Indicators of climate change, the worldwide decline in biodiversity, the consumption of natural resources or emissions of pollutants give rise to a gloomy diagnosis (IPCC SR 1.5, 2018; WWF, Living Planet Report 2018). This not only raises ethical issues because human actions lead to the mass and irreversible extinction of plant and animal species (according to current estimates, between 20,000 and 60,000 species per year). Also, emergencies and social conflicts such as droughts, contaminations, food shortages, flooding, weather-related disasters or the worldwide

DOI: 10.4018/978-1-5225-9188-7.ch009

migration flows are related to ecological problems. And last but not least, it can be said that in the continuation of current developments, the human species itself is threatened, as it massively damages their natural livelihoods.

Against the background of these problems and corresponding recommendations of science to politics since the 1970s (Meadows et al., 1972), it is not surprising that sustainability is on the political and economic agenda today. Sustainable Development is not only courteous in the description of many companies, but also a guideline of organizations, governments and transnational institutions - since 2007 also among the central goals of the UN (http://www.greeningtheblue.org/our-approach/introduction/the-mandate). However, it cannot be overlooked that, despite many declarations of intent and the readjustment of "values," neither in political action nor in the ecological problems in recent decades has much changed for the better. A socio-cultural change in the sense of a pro-environmental transformation of (world) society has not yet occurred. It has long been clear that the lack of political will is only part of the problem and its escalation. In addition, the lifestyles practiced in affluent societies are of crucial importance. They lead to resource consumption and pollutant emissions that are by no means sustainable. That and to what extent this is the case is shown by calculations on the "ecological footprint", which were developed in the 1990s and illustrate the ecological impact of individuals, organizations, companies or even national states (Wackernagel & Rees 1996). If all the people of this earth were above the average lifestyle of the well-to-do citizen of our (world) society, we would need 1.7 Earths in the present (!), according to the latest figures (www.fooprintnetwork.org).

Obviously, the practice of lifestyles relevant to ecological problems is related to consumer issues, that is, to the quantities and qualities of various material resources necessary for the creation and maintenance of lifestyles. Accordingly, it is consumer choices that dominate the ecological footprint (EF) of individuals (see Dooren & Bisshaert 2013, 71) and socio- demographic factors, most notably income, are the key determinants of EF (Bleys et al., 2018). With the amount of available capital grows the possibilities of consumption and thus the actual consumption of the respective individuals. With this in mind, the lifestyles of the wealthy on earth - and not the lives of the world's poorer and poorest - pose a threatening problem to the planet's ecosystems. This also applies under the conditions of computerization of the world society and a "fourth industrial revolution" with which social inequalities could once again intensify (Schwab 2016).

From this it follows, that the growth in prosperity in the poor regions of the world goes along with a further escalation of the ecological crisis. The technical potentials of >sustainable consumption< won´t be able to solve this problem. Because even this form of consumption produces pollution and wastes energy and other ressources. Required is an extensive transformation of society, including a degrowth economy amongst others (York & Rosa 2003). In fact, one could even say that the idea of sustainable consumption pushes a problem when it obscures more effective solution options (such as non-consumption) and, instead, promotes the illusion that there are environmentally neutral forms of consumption. The rhetoric currently unfolding in public discourse on the future of "Mobility 4.0" provides an example of this. With regard to electric drives in buses, trains and cars, this is often referred to as "emission-free" driving, not only in the advertising of providers (for example, automobile industry), but also on the part of politicians or journalists. This misconception preponderates as the current potential of digitization is by no means used only to save traffic. At the same time, it should serve the increasing individualization of mobility behavior - right through to energy-intensive technologies such as the taxiplane.

If the lifestyles practiced are a problem, then the question arises of how behavioral changes towards more sustainable lifestyles can be promoted and - one step earlier: which reasons so far prevent a corresponding change. There are various research approaches for this. They are related to psychological motivational research, concepts of educational sciences or pedagogy (Meyer & Reguant-Closa 2017). The present contribution aims to supplement these perspectives with a sociological one that asks which social reasons are relevant in the field of environmental action and what conclusions can be drawn from this for the digital (self-) management.

The argumentation of the text is based on three central questions, which are dealt with in the following sections:

1. Why is ecological self-management necessary?
2. Which social reasons can be defined as barriers to ecological self-management even under conditions of current digitization (the fourth industrial revolution)?
3. What are the conclusions for solution-oriented communications of the environment-topic, be it in politics, business, NGOs or social movements?

WHY IS ECOLOGICAL SELF-MANAGEMENT NECESSARY?

It would be naive to assume that a shift towards environment-friendly behavior of individuals solves the problems. Rather, the political regulation of various processes, which endanger eco- systems, will be considered indispensable. Proposals range from charges for pollutant production, to sustainability norms and the integration of environmental education into school curricula, to "taxes on unsustainable behavior as meat-oriented diets" (Bleys et al 2018, 205f.; Peschel et al 2016; Hess 2010).

In the context of a system-theoretical perspective, however, a very skeptical picture emerges of the chances of success of a political management. This applies at least to the work of Niklas Luhmann, who in his study “Ecological Communication” (1985) raises the question of how society can adapt to the ecological threat. In the course of long-term historical processes, so his argument, politics evolves as a universal functional system of society. Like the other systems (economics, law, science, art, education et al.), politics is capable of resonating for environmental issues only within its own medium and associated guiding distinctions (“codes”) – at least as long as a second coding such as e.g. sustainable / unsustainable is missing (Godemann / Bartelmeß 2018).

The decisive factor in the case of politics is the allocation of relative power over offices into which the rulers (in the case of democracies) are elected. You hold an office or not - the possibility of participation in political decisions depends on that.

The political enforceability of a “green economy” (Richardson 2013) is therefore tied to the approval of voters -- as is the enforcement of all other issues on the political agenda. Politicians, in their rhetoric and certainly in their actions, can only be environmentally oriented insofar as they believe that they will regain power on the basis of their actions in the next elections. An example for the indicated restrictions gives the history of “The Greens” in Germany. Initially marked by clearly pro-environmental demands (eg a drastic increase in gasoline prices), their representatives barely speak out in a current scandal surrounding fraud in the auto industry, are also moderately on the topic of agricultural turnaround and have recently agreed to expand Germany’s largest airport without disruptive conflicts. Another example is the current debate about the induction of a CO_2 tax in Germany.

Limitations of political influence continue to arise from the fact that the influence on the other systems (such as the law or the economy) must ensure their continuation and regeneration. Last but not least, political power is structurally limited by territorial restrictions of its code (states, nation states, confederations of states). The political struggle for climate protection in the absence of effective political transnational institutions or even a representative democracy of the world society is a striking example of this. In addition, problems such as overfishing and pollution of the oceans or pollutant emissions do not stop at national borders and, as transnational phenomena, require the cooperation of different powers.

A comparable systemic logic is evident in the field of economics where the medium of money determines the room for maneuver with regard to environmentally friendly economics. For instance, a company that offers sustainable products and services to the market can only do so to the extent that buyers are willing to pay the prices. A business enterprise in which the costs permanently exceed the revenues cannot exist on the market, because the economy can reproduce its operations exclusively with the medium of money. The political influence of price formation, for example through emissions trading, taxes or subsidies, therefore has a limit, which can be observed in the market. If the prices of products are so high that they have no or too few buyers for a cost compensation the supplier has a problem as well as when prices fall so much that its production is no longer profitable. This applies to sustainable products as well as to those that are produced without considering environmental aspects (Luhmann 1990; Fischer 2018). The ability to meet financial obligations limits the ongoing of economic processes. This determines the competitiveness of the economy for environmental problems - despite all the influence of politics.

Here is not the place to deepen this system-theoretical perspective. But these few hints indicate that neither politics nor the economy alone will succeed in managing the ecological crisis successfully. On the contrary, one can agree with observers who assume that in addition to technological innovations and political steering, a change in human behavior and lifestyles practiced on an individual level is urgently required (Jackson 2009). Hence, the transformation to a sustainable society can only be achieved with the participation of subjects who, on the basis of their free will, make decisions for more sustainable behavior.

In any case, this is true in the context of democratic political systems, which have many control options (eg laws, taxes), but hardly the right to restrict lavish lifestyles in all its dimensions (clothing, housing, mobility, food, etc.) without departing from the basic principles of the modern constitutional state as well as from older ideas of social order such as property and money (Luhmann 1974).

From a socio-philosophical perspective, it also seems questionable whether and to what extent the silver bullet should be seen in legal or political regulations (Hasnas 2009). Even more raises the question of which other options next to and with political action could serve as a problem solver. Luhmann (1990), for example, attaches particular importance to the forms of protest - they are capable of generating irritation, and of changing systems at least at the level of their programs (eg laws in politics, prices in the economy), but with the danger of too much or too little resonance. Other studies show that collective action can be successful (Botsman & Rogers 2010; Heinrichs 2011; D´Alisa (Ed. 2015); Schmidt 2016). In an analysis of an ecologically active community, Boyer (2016) concludes that community-participatory action is particularly successful in larger groups (municipalities) (Beachcroft-Shaw & Ellis 2017). Also environmental education (Obach 2009; Dooren & Bosschaert 2013, 71,) or environmental ethics is an option, although a certain skepticism seems appropriate here as well, because insofar schools and universities convey environmental education as (eg testable) ‘knowledge’, educational content does not necessarily lead to behavioral changes.

However, one assesses these possibilities: without a new “culture”, without new everyday practices that involve a new self-management of individuals, an ecological transformation of society will not succeed. Such a development is all the more urgent as there are numerous relationships and interactions between political action and individual (consumer) behavior. So it is easy to assume that the policy would drive sustainable economic activity much faster if it recognized a genuine willingness on the part of consumers to share the consequences of political measures (Reisch & Bietz 2011).

But why is it so difficult for people to align their lifestyles with sustainability goals? So far, this question seems to be treated more in environmental studies and multidisciplinary psychology (Bley et al., 2018, 189) than in sociology (Jaeger-Erben M. & Rückert-John, J. 2016). Following sociological perspectives and findings, one can gather a number of arguments that are important in this subject area and, accordingly, should be considered more strongly in a creative management of the problem than previously.

The Challenge of Changing the Lifestyle - Sociological Perspectives

Of course, there are many different reasons why it is hard for us to change our lifestyles. Just think of the force of habit and the amenities of many consumer offerings, e.g. in the field of food, to pick out only one area of life: From the forms of shopping (convenience products in the supermarket) to the devices of storage and preparation (refrigerator, stove, microwave, toaster, etc.), we are interwoven in a complex network of easily consumable offers that allow an effective as well as pleasant lifestyle.

The event character of many consumer goods is furthermore important. Consider the “fun” offered by media entertainment (film, internet, etc.) as well as by mobility technologies (driving, flying, cruising, etc.). The attractiveness and incentives of diverse goods are, on their own, very important reasons why it is not easy to practice sustainable consumption: Because it is difficult for us to renounce these pleasurable experiences. This is even more so, as an ecological self-management is not only related to the choice of more sustainable products, but primarily with reduced consumption. All the more urgent is the question of what deeper social reasons prevent us, in addition to and with those just mentioned, from making our lifestyle more environment friendly and developing a new life practice, indeed an “ecological habit”, which, once established, could also have an effect on subsequent generations mediated by socialization or enculturation.

Functional Differentiation, Identity and Consumption

Only in the last few centuries does a subject-form emerge that demands self-management in the service of an individual ‘identity’ (Luhmann 1986). Regarding the question of why identity becomes a relevant topic for the individuals of modern society, in the social sciences, despite the heterogeneity of the various lines of argumentation, there is a broad consensus regarding a fundamental explanatory pattern. This reflects processes of rationalization, functional differentiation, medialization and de-traditionalization as conditions for the emergence of processes of individualization (see Luhmann 1986). While in stratified societies, familial origins severely regulate the various spheres of existence for the subjects, the development of social identity and biographical development is now considerably less (pre-) structured. Thus, it necessarily comes to a permanent self-care of modern subjects in terms of ‘identity’. The latter must be “managed” in the “multi-option society” (Gross 1995) on its own initiative - the term “a hand crafted existence” (Hitzler/Honer 1994) is one among others, which brings this issue to the point.

In this sense, it is understandable that ‘identity’ has long been a successful offer of the ‘cultural industry’. Modern consumption, driven by technological developments and industrialization (Siegrist, Kaelble & Kocka Ed. 1997), is a sphere of action in which subjects design their identities and make them visible to others. As early as 1899, Thorstein Veblen (1994) [1899]) spoke of a “conspicuous consumption” that is particularly relevant under the anonymised conditions of metropolitan life, because people know each other less than before through a common past and therefore signalize about possessions, who they are or would like to be. In the course of modernization processes (functional differentiation, technical and media developments, etc.), subjects are increasingly responsible for the development of their individual identity and for belonging to groups. Starting with the first industrialization, consumption has developed into an important sphere of action in this context.

The coupling of consumption and identity is all the more difficult because relative ownership and participation in consumption can no longer be attributed to the fate of social class as easily as under the conditions of a stratified society (Elias 1998). Poverty, a lack of education or other problems now seem stronger than ever before as signs of individual failure, as individual incompetence, lack of effort and achievement - even when there was no equal opportunity for the individuals concerned. The sphere of consumption also includes the idea of the meritocracy, including the idea that a more in ‘having’ also means more ‘being’ and individual achievement.

Design, Fashion, Image and the Social Orders of Consumption

In the course of developments as functional differentiation, rationalization and industrialization, numerous professions and forms of enterprise emerge in society, which contribute to a strengthening and differentiation of the coupling between identity and consumption. From the consumer goods of everyday life, the fashion or furniture to electronic devices or means of transport: Everywhere we are confronted with objects of the cultural and lifestyle industry (advertising, design, mass media entertainment, etc.) which are highly loaded with identity-related meanings. Against the background of this historically developed situation, it is understandable that social psychology then speaks of possessions as "extended self" (Belk 1988).

And because there is no longer a universally acknowledged "fine society" (class) in many regions of the mediatised, functionally differentiated (world) society, and one that is capable of acting as a model in matters pertaining to taste, then we can concur with Elias's (1998 [1935]) view when he observed at the beginning of the twentieth century how "uncertainty over form" and "uncertainty over taste" was now predominant. This explains why mass medial genres like advertising, entertainment and other institutions of the culture industry continually assume the function of producing models of 'good taste' and are presented in materialized manner in the broadly contoured, differentiated market of consumer goods.

Since the twentieth century, different lifestyles have been developed, strongly based on consumer-goods, visible aesthetics and images (Kautt 2008). And one can say that the emerging forms of communitarisation in the twentieth century, such as youth-, pop- and sub-cultures (Tenbruck 1965, Hebdige 1979) or even theme-oriented scenes (Hitzler & Niederbacher 2010), are comparable in beeing commodities with a specific aesthetic. Insofar as these developments are linked to the dynamics and relevance of the principle of fashion, they stand in the way of sustainable consumption, since it is inversely dependent on the durable use of goods.

Habits and Status-Hierarchies

As Pierre Bourdieu (1977) notes, lifestyles cannot be freely chosen, but are largely the result of socialization processes. In these act a dialectic of external circumstances and personality, which produces a "habitus" as a scheme of thinking, feeling, communicating and acting (Bourdieu 1977). Also in the "open" society of the present with the connection between identity and consumption suggested above, socialization processes influence the lifestyle of individuals. This is all the more so as the habitual imprints are related to all the capital types so called by Bourdieu, namely economic capital (property, money), social capital (friends, networks) and cultural capital (knowledge, education). It is therefore all the more important to explore the potentials of sustainable consumption within the framework of sociological theories of practice and to draw conclusions for (for example) political influence on practices (cf. John R. et al. 2016).

In spite of the above-mentioned tendency to decouple strata and taste and in spite of an enforced self-management of identity, social inequalities and hierarchies are accordingly reproduced. These include milieu-related normative orders and worldviews that determine the reflection on lifestyles. For example, Bourdieu speaks of a "needs dictated taste" (Bourdieu 1984) of the working class as a value orientation that clearly differs from the "refined" taste of the middle and upper classes. While an "ecological" lifestyle in the perspective of the needs dictated taste can be regarded as an improper abundance, it is suitable in the higher class for the distinction and demonstration of economic and cultural capital. It follows, among other things: styles of eating, clothing, living, cultural entertainment or even mobility are structured by socialization processes that cannot be easily changed.

Values, Knowledge, Complexity and Self-Delusion

Another obstacle on the way to a more environmentally friendly life practice are value orientations and knowledge of ecological problems. On the one hand, individuals are not motivated to act in an environmentally friendly way if they do not know about the problems and sustainability is not a positive value for them. In a sense, it is true that value orientations are an important variable for action (see Kirk / Kasser 2005). At the same time, studies suggest that environmental knowledge and values, as well as personality traits, play a minor role, while sociodemographic variables (age, education level, income et al.) and general environmental concerns are more important (Bleys et al 2018, 203).

Therefore, the presence of knowledge about the ecological crisis and right attitudes does not necessarily imply pro-environmental behavior. An example is the meat consumption. It is obvious that we eat meat despite better environmental knowledge and often despite ethical concerns. Very many people know that their diet is not only ethically problematic (factory farming, killing animals for the purpose of meat production), but also brings massive ecological problems (see Dagevos, H., & Voordouw, J. 2013; Peschel et al., 2015). Likewise, we know that cycling is more environment friendly than the car, plastic pollutes the environment and the monotonous lawn of our front yard promises no biodiversity. And yet, in all these areas of action, we are always reproducing ecologically problematic behavior in spite of better knowledge.

The gap of knowledge, value orientations and action is in focus of many studies (e.g. Kennedy et al. 2009; Entzian 2015). These include methodological problems in capturing individuals' knowledge and self-assessments. In the present context, the aspect of social desirability for example plays a role. As respondents are aware of the general acceptance or norm of environmentally responsible behavior, they state a corresponding attitude in surveys, even though they themselves do not share them. Referring back to the relationship of consumption and identity put above, one could say that keep up their lifestyle-identity in factual action, but in surveys, they design a self that is adapted to universally accepted guiding values.

It could also be that the complexity of ecological problems as well as the complexity and heterogeneity of environmental knowledge disseminated in the media foster a certain self- deception of the subjects or blocks action. The less one actually knows exactly to what extent the individual dimensions of one's own actions (mobility, energy, clothing, nutrition) are ecologically important, the easier it is to classify one's own actions as "ecologically correct". In any case, empirical studies on the self-assessments of individuals usually do not provide any information on ways in which the respondents are able to correctly assess their behavior: „Non of the footprint papers has looked to the extent to which the people are able to self-assess their environmental impact, so that it is difficult to predict whether the reported discrepancies between self-assessed and objective measures of pro-environmental behavior will be reproduced for environmental impacts." (Bleys et al. 2018, 193).

Moreover, the dimension of knowledge can become a direct barrier. Namely in the sense that subjects (consumers), against the backdrop of diverse and sometimes contradictory information, cannot gain any evidence of 'right' action and thus refrain from looking for alternatives. Something similar happens in the context of the so-called "Cassandra syndrome" (Fields 2017: 3), ie when prognoses for the future are known but labeled as untrue. Mass media reports give an example, insofar divers informations produce intransparency -- just think of the denial of climate change by strategically operating actors in politics and economics as Donald Trump.

In any case, environmental knowledge questions other knowledge and, like any scientific knowledge, is fundamentally subject to the possibility of being verified and falsified. Knowledge is therefore ambivalent as a motivator of environmental action: For not only the individual, but entire states can postpone or refrain from actions in reference to ignorance. Even though governments commission further research, ignorance is not eliminated, only the relationship between knowledge and ignorance is shifted – so again a demand for new knowledge is generated.

Culture, Fetishism, Relinquishment and Missing Role Models

Another deep-seated obstacle to the ecological transformation of society is the fact that the transgression of pure physical needs is a basic need of human beings. Thus, an essential function of even the oldest cultures is to transcend the boundaries of the corporeal. The meal is one of the oldest institutions of humanity in this sense: it enforces its social orders (times, places and rules of eating together) against the merely physical satisfaction of the individual and thus makes the participants 'cultural beings' (Simmel 1997 [1910]). Also, cultic and religious ceremonies or festivals with their abundance (eg of food), their intoxication and their ecstasy are socially organized events of the crossing of the border in which humans experience more than mere life.

In this sense, Balint Balla speaks of culture as an "existential sphere of coming to terms with deficits" (Balla 1987) – a perspective, that can be related to specific historical problems. Concerning the development of sustainable lifestyles, the terms “alienation” and “fetishism” and their context bring us closer to the cultural dependence on consumer styles. Following Karl Marx (1987 [1872]), the origin of modern commodity-fetishism can be seen in phenomena of alienation, which arise from modern capitalism (gainful employment = alienation of property and holistic production processes). Also processes of functional differentiation and rationalizations contribute to a general problem complex. They bring individuals into a socio-structural external position, which increasingly transfers the participation in society into the sphere of responsibility of the subjects. In addition, there is an increasing lack of social orders that meaningfully integrate the spheres of human existence. Although the thesis of the dwindling significance of religions can be relativized and differentiated, it is still hard to overlook the fact that religions currently only act to a limited extent as the “existential sphere of coming to terms with deficits” and accordingly cultural institutions must appear as functional equivalents - especially the sphere of Consumer Culture (Featherstone 2007).

Although clothes, household items, electrical appliances or cars may not appear to one or the other as culture and one is inclined to associate certain goods such as art, music or literature with the concept of the cultural, this is a common bond of the cultural: both rise the human being above the absolutely necessary and therefore makes him a cultural being. Against this background, another reason for the difficulty of abstaining from consumption becomes clear: Insofar as there is a lack of functional equivalents of culture in contemporary society, people who are no longer consuming appear to be dehumanized beings. The permanent attachment to a fetishistic consumption pattern is all the greater, as the disappointed expectations after the purchase of a product are compensated by renewed consumer actions. Accordingly, one can see in disappointed expectations an important driver of capitalism (Baudrillard 1982).

Normality and Order

Another barrier to sustainable lifestyles comes from notions of normality and order. These ideas deserve a closer attention because they belong to the basal cosmology of a society that transcends the different social milieus (classes, subcultures, lifestyles). In relation to the consumer culture of today’s affluent society, this means, for example, that owning specific goods (cars, televisions, smartphones, refrigerators, etc.) belongs to a “zone of normality” (Link 1997), to a zone of what is commonly expected about the possessions of individuals. At the same time, the zone of the “normal” constitutes a space of deviance, into which fall all those who do not have these things - for whatever reason. It follows that outside of this zone losses of appreciation or stigmatizations threaten.

Another problem, besides and with (consumer) ideas of normality, are ideas of order. As Mary Douglas points out in her work "Purity and Danger" (1995 [1966]), the classification of pure and impure belongs to the basic codes of social reality of most diverse cultures. That and to what extent these ideas currently have an effect on our dealings with nature can be found, for example, in (almost) all gardens in settlement areas around the world: Above all, they serve as a demonstration area of order. Areas on which so-called "bad weeds" sprout or wood is left to the natural decomposition process are considered neglected, chaotic and easily become the subject of social conflicts in neighborhood relations. Ideas of normality, and not values such as biodiversity determine action and the relationship to nature. This is all the more problematic as this cosmology is also clearly visible in dealing with property of the public sector (such as municipal green spaces).

Reflexive-Critical Distancing and Devaluation of Ecological Lifestyles

Another barrier to the development of pro-environmental lifestyles is related to mass media and scientific discourses that critically deal with (relatively) sustainable products, their production and use. While these voices may, in principle, be helpful to advance the ecological transformation of society, they tend to be limited to presenting specific problems and leaving the benefits and potentials unmentioned. The main arguments are:

a) The naïve consumer: The mass media are currently reporting on the topic of ecological crises repeatedly in conjunction with naive consumers who believe that they can solve the big problems with their consumption behavior. The naïve do- gooder is a persistent topos of media in the context of reflecting on pro- environmental behavior.
b) The dubiousness of consumer decisions: Reports often refer to the complexity of eco-balancing, e.g. in the context of the topic of organic food. These appear questionable because they among other things (as conventional products) make long transport routes necessary.
c) Non-transparency and fraud scandals: There are scandals even among providers with certified labels (though very rare in Germany, for example). Certificates such as "sustainable fishing" or "sustainable forestry" are sometimes problematized because of lack of transparency and dubious forms of self-regulation. Also globally operating NGOs, which have considerable budgets (such as Greenpeace or the WWF), are occasionally criticized.
d) Green-washing and image work: Companies that do not develop their own production cycles sustainably, but donate money for environmental projects, are

accused of image-work and green-washing. This is especially true when their actual business activities are easily identifiable as harmful to the environment (for example, agribusiness, pharmaceutical companies, fossil energy industry).

e) Sociological Enlightenment: The sociological description and explanation of pro- environmental behaviors is contra-productive insofar as it does not refer to this action as a reaction to environmental problems, but only to social functions within socially constructed reality. Three lines of argumentation are particularly frequent here: 1. According to concepts such as those of Pierre Bourdieu, sociology recognizes sustainable lifestyles as a distinction medium of rich middle and upper-class milieus. In this perspective, they benefit from sustainable consumption, while the poor are limited to their need-based consumption. Moreover, as process of distinction, sustainable consumption is a kind of green-washing of affluent individuals that obscures and stabilizes the structural problem (capitalism, neo-liberalism). 2.: Pro- environmental behavior is also deconstructed as a medium of sense-making in late modernity. In this perspective, ecological lifestyles appear as quasi-religions in an alienated, secularized society. 3. Pro-environmental lifestyles enable subjects to feel moral superiority and motivate moral communications that can be harnessed in the struggle for prestige.

In the synopsis of these aspects one can say that in society there is a dense network of concepts, arguments and (stereotypical) typifications that distance, criticize and morally discredit pro- environmental lifestyles. The fact that sustainable lifestyles can be used as media of distinction, meaning and moralizing should certainly not be disputed here (Neckel 2018). Much more decisive for the question pursued here, however, is something else: namely, that precisely this criticism creates a very bad starting position for the transformation of society towards the much- needed ecological self-management of subjects. In fact, one can recognize in the critique of sustainable lifestyles an important social function, of which sociology clearly does not like to speak: this function is to stabilize and legitimize the current hegemonic lifestyles.

Well-known stereotypes such as the dogged and morally hypocritical >greenie< or vegetarian clearly illustrate this: they are not least social figures with which the majority society distances environmental problems and assures its own of its "realism" as well as of its moral integrity and superiority: the greenie is it, who believes that his consumption will save the world, who is not able to uncover green washing, and strives in vain to gain some sense, distinction, and moral goodness from his joyless existence. Anyway, in mass media discourses of contemporary society - with the help of social sciences - a great effort is made to understand the ecological crisis as a result of all sorts of structural circumstances, but hardly as a result of lifestyles thatwe people practice in the prosperous regions. The modern consumer is relieved by a critical rhetoric, can maintain its consumption habits and does not have to face the contradictions which occur in developing sustainable consumption in its own realm of action. Instead, keywords such as "neo-liberalism" and "global capitalism" latently address the responsibilities to those in power in politics and economics. The associated narratives get in the way of a simple insight:

To behave in a pro-environmental way, individuals need to believe that their actions can make a difference (Bleys et al 2018: 190).

Digital Self-Management: Problems and Recommendations

If one follows the previous considerations, it becomes clear that in addition to and with psychological motivations (Ryan, R. & Deci, E. 2000) and in addition to current attitudes and values, there are various, historically evolved social reasons that a pro-environmental self- management become unlikely. The allowance of these reasons is essential for a management, if it wants to change the individual action - be it as political management, as consumption management (eg advertising and marketing) or as management of organizations and NGOs, which want to achieve a more sustainable lifestyle.

This also applies in the age of a "Fourth Industrial Revolution" (Schwab 2016), in which processes of digitization are making all areas of society dynamic and changing – also in the realm of consumption. Just think of electronic payment systems, consumer tracking, personalized advertising, influencers on social media or the differentiation of markets via online platforms. The computerization of society also opens up new potential for action, which could be used for a shift towards more sustainable lifestyles. Examples of this are smartphone apps, which allow an individual ascertainment of the ecological footprint or product comparisons under environmental aspects. Even social movements, which can organize protest or petitions via social media, develop new forms under these conditions.

However, the above-mentioned social barriers are also effective under digital conditions and it can be assumed that the probability of socio-cultural change towards pro-environmental action does not >automatically< increase with technically structured action potentials. The development of an "ecological habitus" (Kirby 2017) is therefore an urgent and demanding project of contemporary society in which social problems, if not solved, but after all must be brought into a different form. Seven perspectives for this are finally listed, corresponding to the sequence of problems outlined above.

Identity Design

The (self-) management of sustainable consumption must take account of the fact that the various facets of consumption, in particular aesthetic dimensions, act as central media for the production and maintenance of individual and collective identity. Since the problem of sustainability overlaps individual social groups (milieus, subcultures, ethnic groups, etc.), the design of the sustainable must be compatible with the "culture" of individual target groups just as it must transcend the differences of group-based everyday aesthetic schemas.

Deceleration

Ecological (self-) management depends on alternatives to the established livestyle industry (fashion, design, advertising). At the same time, these alternatives have to adapt to the same social problems as current consumer goods: Sustainable consumption must also provide security in matters of taste in a society where there is a lack of taste due to socio-structural reasons (see above). An essential challenge, then, is to create and popularise images that do not follow the short-lived dynamics of fashion and its constant self-obsolescence, but instead establish persistence in design as a positive value.

Milieu- und Status-Design

Milieu-bound socialization processes have an effect not only on identity and taste preferences, but also on moral evaluations, normative orders and value orientations. For the enforceability of a pro-environmental (self-) management, therefore, the insertion of >environmental orientation< into existing orders of prestige is significant.

Emotions and Facts

Since knowledge seems to contribute only to a limited extent to pro-environmental action, whereas concern for the environment is more likely to do so (Bleys et al 2018), the further accumulation of knowledge offers itself only to a limited extent as a (self-)management strategy. Knowledge is particularly helpful if it is convincingly related to concrete actions (for example: apps for CO_2-balancing of individual flights) or when it opens up concrete options for action (for example, apps for product comparison). Here and there knowledge can counteract self-deception and repression processes. For example in computerized society knowledge can be helpful if it is pointing to the enormous energy demand of digital technologies and the Internet, which stands in significant contrast to the "green cloud imaginary"

(Carruth 2014, 348). Besides and with knowledge mediation, forms of emotional design via visual communications are probably of great importance. In the future, these could not only contribute more to the revaluation of sustainable lifestyles but also to the devaluation of unsustainable lifestyles - all the more so since visual communication against forms of linguistic criticism is strongly immunized.

Balancing of Being and Having

If the function of culture is tied to (temporary) wastefulness and extra-ordinary life, the (self-) management of sustainable consumption styles must make offers for it. The same applies to fetishism as a symptom of modern alienation processes. The design, communication and practice of sustainable lifestyles must make it clear that, and to what extent sustainability, in spite of consumption reduction, can make extra-ordinary and (temporary) waste a tangible experience and that, despite a downgrading of the consumer balance, fetishes remain to which the desire can be directed.

Shifting the Normality-Zones

In order to anchor sustainability practices and (voluntary) consumption decrease more broadly in society, it will continue to be important to "normalize" appropriate practices in various areas of life (clothing, nutrition, mobility, etc.). Sustainable lifestyles should not appear as a deviant behavior of dogmatic nerds. Rather, they have to become mainstream culture. The same holds true for notions of order related to nature (for example, gardens). Social events, where individuals develop and experience new social practices in common with others, could be particularly helpful. Because they involve individuals in a community, they bring the issue out of a zone of silence and non-transparency, and bring environmental action into the 'normality zone'. The testing and further differentiation of innovative forms of sustainable consumption is therefore of particular importance (for a description of current forms cf. Jaeger-Erben M. & Rückert-John, J. & Schäfer M. 2018). It is easy to imagine that practically oriented events with group-interaction character in educational institutions, companies and organizations can make an important contribution to an ecological transformation (Fields & Atiku 2017). The promotion of a participatory design (Cross 1972; Mareis & Joost 2013) in connection with environmental products and services should also be considered in this context. With the involvement of users in the entire design process, aesthetic preferences and values become just as visible as resistances, which must be overcome in the development of sustainable lifestyles.

CONSTRUCTIVE CRITICISM INSTEAD OF REPRESSION

Intellectuals who are critically concerned with sustainability in scientific and / or mass media discourses should not limit themselves to a “de-mystification” of sustainability concepts and practices, but should participate in their improvement by concrete suggestions. A task of critical analysis would be e.g. to describe in more detail the complex societal repressive machinery that has so far enabled us not to change our lifestyles despite our better knowledge of the ecological crisis.

CONCLUSION

If one agrees with these findings, it becomes clear that a significant problem of an ecological transformation movement so far is that it can do little to oppose the positive language of things, goods, their aesthetics and semantic charges (inter alia, through advertising and entertainment). Insofar as pro-environmental action means diminish consumption, it is - so it seems at least so far - an action without objects that structure desire, an action without fetishes, or at least an action with less fetishes. There is a lack of models that make a sustainable lifestyle attractive, desirable, and last but not least, a way of life that does not entail loss of face, but can even contribute to a positive image.

Even if it is by no means an empirically-analytically developed diagnosis, one can conclude from the background of what has been said in the sense of a working hypothesis: Whether and to what extent pro-environmental action becomes an element of everyday practice depends greatly on the extent to which a new culture can be established, in which communication and action are so intertwined that the problem horizons mentioned above are taken into account.

In conclusion, one can say that these considerations do not immediately lead to action strategies for practice. However, one can assume that a more detailed description of social problems provides a starting point for creative solutions that are just adjusted to this. Accordingly, the arguments presented complement such perspectives as those of social marketing (Beachcroft- Shaw & Ellis 2017), that tend to concrete changes in behavior. That and to what extent the description of the problems diagnosed here can be used for practical actions, has to be shown in further case-related studies.

REFERENCES

Balla, B. (1987). Kultur als Daseinssphäre von Knappheitsbewältigung. In W. Lipp (Ed.), *Kulturtypen, Kulturcharaktere. Träger, Mittler und Stifter von Kultur* (pp. 241–256). Berlin: Reimer.

Baudrillard, J. (1982). *Der symbolische Tausch und der Tod*. München: Matthes und Seitz.

Beachcroft-Shaw, H., & Ellis, D. (2017). Social Marketing to Achieve Sustainability. In Z. Fields (Ed.), *Collective creativity for responsible and sustainable business practice* (pp. 296–314). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-1823-5.ch016

Belk, R. W. (1988). Possessions and the Extended Self. *The Journal of Consumer Research*, *15*(2), 139–168. doi:10.1086/209154

Bleys, B., Defloor, B., Van Ootegem, L., & Verhofstadt, E. (2018). The environmental impact of individual behavior: Self-assessment versus the ecological footprint. *Environment and Behavior*, *50*(2), 187–212. doi:10.1177/0013916517693046

Botsman, R., & Rogers, R. (2010). *What's mine is Yours. The Rise of Collaborative Consumption. How Collaborative Consumption is Changing the Way o Life*. New York: Harper Collins UK.

Bourdieu, P. (1977). *Outline of a Theory of Practice*. New York: Cambridge University Press. doi:10.1017/CBO9780511812507

Bourdieu, P. (1984). *Distinction. A social Critique of the Judgement of Taste* (R. Nice, Trans.). Cambridge, MA: Harvard University Press. (Original work published 1979)

Boyer, R. (2016). Achieving one-planet living through transitions in social practice: A case study of dancing rabbit ecovillage. Sustainability: Science, Practice, &. *Policy*, *12*(1). doi:10.1080/15487733.2016.11908153

Brand, K.-W. (2017): Zur Problematik der Steuerung sozial-ökologischer Transformationsprozesse. In Die sozial-ökologische Transformation der Welt, (pp. 117-154). Frankfurt: Campus.

Carruth, A. (2014). The digital cloud and the micropolitics of energy. *Public Culture*, *26*(2), 339–364. doi:10.1215/08992363-2392093

Cross, N. (Ed.). (1972). Design Participation. In *Proceedings of the Design Research Society's Conference*. London: Academy Editions.

D'Alisa, G. (Ed.). (2015). *Degrowth: a vocabulary for a new era*. New York: Routledge.

Dagevos, H., & Voordouw, J. (2013). Sustainability and meat consumption: Is reduction realistic? *Sustainability: Science, Practice, & Policy, 9*(2).

Dooren, C. v., & Bosschaert, T. (2013). Developing and disseminating a foodprint tool to raise awareness about healthy and environmentally conscious food choices. Sustainability: Science, Practice, &. *Policy*, *9*(2), 70–82. doi:10.1080/15487733.2013.11908116

Douglas, M. (1995). *Purity and Danger: an analysis of the concepts of pollution and taboo*. London: Routledge. (Original work published 1966)

Elias, N. (1998). The Kitsch Style and the Age of Kitsch (E. Jephcott, Trans.). In J. Goudsblom & S. Mennell (Eds.), The Norbert Elias Reader: A Biographical Selection, (pp. 26-31). Oxford, UK: Blackwell.

Entzian, A. (2015). *Denn sie tun nicht, was sie wissen. Eine Studie zu ökologischem Bewußtsein und Handeln*. München: oekom.

Featherstone, M. (2007). *Consumer Culture and Postmodernism* (2nd ed.). London: Sage.

Fields, Z., & Sulaiman, O. A. (2017). Collective Green Creativity and Eco-Innovation as Key Drivers of Sustainable Business Solutions in Organizations. In Z. Fields (Ed.), *Collective creativity for responsible and sustainable business practice* (pp. 1–25). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-1823-5.ch001

Fischer, R. A. (2018). Towards Sustainable Global Value Chains: The Role of The Group of Seven. In A-M. Schneider & S. Jastram (Eds.), Sustainable fashion. Governance and new management approaches, (pp. 25-39). Cham: Springer.

Godemann, J., & Bartelmeß, T. (2018). Gesellschaftliche Verständigung über ein Totalphänomen. Zum Verständnis nachhaltigkeitsbezogener Ernährungskommunikation. In T. Phyel (Ed.), Zwischen Ohnmacht und Zuversicht. Vom Umgang mit Komplexität in der Nachhaltigkeitskommunikation (pp. 187-206). München: oekom.

Gross, P. (1995). *Die Multioptionsgesellschaft*. Frankfurt am Main: Suhrkamp.

Hasnas, J. (2009). Two Theories of Environmental Regulation. *Social Philosophy & Policy*, *26*(2), 95–129. doi:10.1017/S0265052509090189

Hebdige, D. (1979). *Subculture. The Meaning of Style*. London: Methuen.

Heinrichs, H. (2011). Participation: Empowerment for Sustainable Consumption. In J. Godeman & G. Michelsen (Eds.), *Sustainability Communication. Interdisciplinary Perspectives and Theoretical Foundations* (pp. 187–198). Heidelberg, Germany: Springer.

Hess, D. (2010). Sustainable consumption and the problem of resilience. Sustainability: Science. *Practice and Policy*, *6*(2), 26–37.

Hitzler, R., & Honer, A. (1994). Bastelexistenz. Über subjektive Konsequenzen der Individualisierung. In U. Beck & E. Beck-Gernsheim (Eds.), *Riskante Freiheiten. Individualisierung in modernen Gesellschaften* (pp. 307–315). Frankfurt am Main: Suhrkamp.

Hitzler, R., & Niederbacher, A. (2010). Leben in Szenen. Formen juveniler Vergemeinschaftung heute (3rd ed.). Wiesbaden: VS. doi:10.1007/978-3-531-92532-5

Honneth, A. (1992). *Kampf um Anerkennung: zur moralischen Grammatik sozialer Konflikte*. Frankfurt am Main: Suhrkamp.

IPCC (Intergovernmental Panel of Climate Change). (2018). *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Geneva, Switzerland: World Meteorological Organization.

Jackson, T. (2009). *Prosperity without growth: Economics for a finite planet*. London: Earthscan. doi:10.4324/9781849774338

Jaeger-Erben, M., Rückert-John, J., & Schäfer, M. (2015). Sustainable consumption through social innovation: A typology of innovations for sustainable consumption practices.'. *Journal of Cleaner Production*, *108*, 784–798. doi:10.1016/j.jclepro.2015.07.042

John, R. & Jaeger-Erben M. & Rückert-John, J. (2016). Elusive Practices: Considerations on limits and possibilities of environmental policy for sustainable consumption. *Journal of Environmental Policy and Governance*, 129-140. doi:10.1002/eet.1706

Kautt, Y. (2008). *Image. Zur Genealogie eines Kommunikationscodes der Massenmedien*. Bielefeld: Transcript.

Kennedy, E. H., Beckley, T. M., McFarlane, B. L., & Nadeau, S. (2009). Why don’t we >walk the talk<: Understanding the environmental values/behavior gap in Canada. *Human Ecology Review*, *16*, 151–160.

Kirby, J. (2017). Fleshing out an ecological habitus: Field and capitals of radical environmental movements. *Nature and Culture*, *12*(2), 89–114. doi:10.3167/nc.2017.120201

Kirk, W. B., & Kasser, T. (2005). Are psychological and ecological well-being compatible? the role of values, mindfulness, and lifestyle. *Social Indicators Research*, *74*(2), 349–368. doi:10.100711205-004-8207-8

Link, J. (1997). *Versuch über den Normalismus. Wie Normalität produziert wird*. Opladen: VS.

Luhmann, N. (1974). Einführende Bemerkungen zu einer Theorie symbolisch generalisierter Kommunikationsmedien. *Zeitschrift für Soziologie*, *3*(3), 236–255. doi:10.1515/zfsoz-1974-0303

Luhmann, N. (1986). The Individuality of the Individual: Historical Meanings and Contemporary Problems. In T. C. Heller, M. Sosna, & D. E. Wellbery (Eds.), *Reconstructing Individualism: Autonomy, Individuality, and the Self in Western Thought* (pp. 313–325). Stanford, CA: Stanford University Press.

Luhmann, N. (1990). *Ökologische Kommunikation. Kann die moderne Gesellschaft sich auf ökologische Gefährdungen einstellen?* Opladen: VS.

Mareis, C., & Joost, G. (Eds.). (2013). Wer gestaltet die Gestaltung? Praxis, Theorie und Geschichte des partizipatorischen Design. Bielefeld: Transcript. doi:10.14361/transcript.9783839420386

Marx, K. (1987). Das Kapital. Kritik der politischen Ökonomie. Erster Band.

Meadows, D. (1987). Die Grenzen des Wachstums (H-D. Heck, Trans.; 14th ed.). Stuttgart: Deutsche Verlags-Anstalt.

Meyer, N., & Reguant-Closa, A. (2017). >Eat as if you could save the planet and win!< sustainability integration into nutrition for exercise and sport. *Nutrients*, *9*(4), 412. doi:10.3390/nu9040412 PMID:28430140

Neckel, S. (2018). Ökologische Distinktion. Soziale Grenzziehung im Zeichen von Nachhaltigkeit. In S. Neckel (Eds.), Die Gesellschaft der Nachhaltigkeit. Umrisse eines Forschungsprogramms (pp. 59-76). Bielefeld: Transcript.

Obach, B. K. (2009). Consumption, ecological footprints and global inequality: A lesson in individual and structural components of environmental problems. *Teaching Sociology*, *37*(3), 294–300. doi:10.1177/0092055X0903700307

Peschel, A. O., Grebitus, C., Steiner, B., & Veeman, M. (2016). How does consumer knowledge affect environmentally sustainable choices? Evidence from a cross-country latent class analysis of food labels. *Appetite*, *106*, 78–91. doi:10.1016/j.appet.2016.02.162 PMID:26944229

Richardson, R. B. (2013). *Building a green economy. Perspectives from ecological economics*. East Lansing, MI: Michigan State University Press.

Ryan, R., & Deci, E. (2000). Intrinsic and extrinsic motivations. Classical definitions and new directions. *Contemporary Educational Psychology*, *25*(1), 54–67. doi:10.1006/ceps.1999.1020 PMID:10620381

Schmidt, I. (2016). *Consumer Social Responsibility. Gemeinsame Verantwortung für nachhaltiges Konsumieren und Produzieren*. Wiesbaden: Springer VS.

Schwab, K. (2016). *The fourth industrial revolution*. Cologny: World Economic Forum.

Siegrist, H., Kaelble, H., & Kocka, J. (Eds.). (1997). *Europäische Konsumgeschichte. Zur Gesellschafts- und Kulturgeschichte des Konsums (18. bis 20. Jahrhundert)*. Frankfurt am Main: Campus.

Simmel, G. (1997). Sociology of the Meal. In D. P. Frisby & M. Featherstone (Eds.), *Simmel on Culture. Selected writings* (pp. 130–137). London: Sage. (Original work published 1910)

Tenbruck, F. (1965). *Jugend und Gesellschaft*. Freiburg im Breisgau: Rombach.

Veblen, T. (1994). *The Theory of the Leisure Class: An Economic Study of Institutions*. New York: Penguin Books.

Wackernagel, M., & Rees, W. (1996). *Our ecological footprint. Reducing human impact on the earth*. Gabriola Island, BC: New Society Publishers.

World Wildlife Found (WWF). (2018). *Living Planet Report 2018: Aiming higher*. Retrieved from https://wwf.panda.org/knowledge_hub/all_publications/living_planet_report_2018/

York, R., & Rosa, E. (2003). Key Challenges to Ecological Modernization Theory. *Organization & Environment*, *16*(3), 273–288. doi:10.1177/1086026603256299

Chapter 10
Through Harmonization of National Technical Regulations to More Sustainability in Engineering Business:
How to Stay Compliant, Efficient, and Sustainable in International Engineering Business

Julia Krause
Chemnitz University of Technology, Germany

ABSTRACT

This chapter provides readers with specifics of complexity in engineering, delivering, and constructing of industrial plants while working in different countries. Export-oriented companies in mechanical and plant engineering businesses with long supply chains face huge challenges in considering different technical requirements for different types of equipment and for different services and procedures they provide, which lead to time and cost inefficiency. In modern times with different economic, social, and environmental requirements on the one hand and challenges caused by globalization, digitalization, and worldwide climate change; on the other, it is vital to find the ways for more sustainable project management and sustainable business models and to inspire global players to consider sustainability development goals and to become an innovator to drive the others: the suppliers, the clients, and other stakeholders. The first step towards sustainable engineering processes in the globalized world is the harmonization of technical regulations worldwide.

DOI: 10.4018/978-1-5225-9188-7.ch010

INTRODUCTION

Different aspects of our modern lives as well as businesses are nowadays on a very high globalized level. To work globally, to be influenced by global partners, to deal with global clients and suppliers, to be open to the new –is the way companies make progress today. The world is changing fast. Global manufacturing and dealing with international companies have become usual and common for lots of industries and companies, and sometimes even essential to survive. Efficiency of all processes of a global acting firm is one of the central arguments in favor of globalization[1]. Another positive influence of globalization is the possibility for local companies and local staff to get better paid jobs, to learn new skills and new technology and therefore globalization contributes to the fourth SDG: Quality Education in poorer countries. But there are of course also a lot of challenges to conduct their work more efficiently and the way they would like: cultural differences, acceptance of own approaches, local regulation. It is also very important for companies to become flexible in order to react quickly to demands of clients and society. In such cases we speak about lean management in introduction new products, new services or just converting the old ones to the new environments. The process might start with just an increase in exports or global sourcing, followed by a small international representation office, growing into a multinational manufacturing organization[2]. But every company and every business, doesn´t matter, whether it is just one delivery or establishment of a daughter company have to deal with issues of the international trade barriers.

Variety of Products and Services

Especially companies in mechanical and industrial plant engineering businesses offer their services and products – from small gadgets, electrical components, machines, pipes, pressure vessels, measuring devices until complete subsystems and package units all around the world. They also source raw materials, semi-manufactured or finished products from hundreds universally working suppliers from different countries, employ international teams and construct plants for international clients in always changing geographical, political and cultural environments.

Apart from thousands of products and devices manufacturing companies have to deal with lots of services of their own or offered by other companies to fulfill various requirements. There are companies specialized in expediting of manufacturing goods, in strength-calculating for the pressure equipment or metal constructions, in testing the equipment, in preparing the required documentation. There are specialized companies working on certain parts of projects, like fire protection, explosion protection, risk analyzing, industrial safety reports, and conducting research and analyzes of the equipment and of the technological solutions. Additionally, there are companies specialized in constructing a plant: usually while working abroad it is important to hire a local company for building activities, companies that have their know how in commissioning of such sophisticated equipment or the whole plants and in organizing all the required procedures for getting the permission for putting the plant into operation[3].

But there is also another product which we have to consider as a vital one and which is not tangible as all typical gadgets and devices: the knowledge. In many times and at different stages of realization of a project a company might need not a product or service but just the knowledge itself. And the amount of new knowledge the company needs is growing with unpredictable speed. There are some reasons behind it: to be effective you have to apply the yet applied knowledge, to build upon the existing experience. But for this reason, you have to find the ways to get that knowledge, to acquire it and to present it to others in the way everyone would understand and apply in the right manner to their issues. This topic is on the frontier of different fields like psychology, pedagogy, knowledge management, innovation management, economics, technology, law etc. and it shows how deep is the complexity of every international project and how important nowadays is the mixture of different topics and abilities to become successful in what one does.

Within a lot of various products and vast number of equipment and different services one should also keep in mind that the plants themselves are of a very divergent nature and therefore absolutely subject to contrasting requirements: it can be a chemical or a petrochemical plant, a plant for oil- and gas industry, a pharmaceutical plant or a food-production facility with strong focus on hygienic issues, fire- or explosion protection or dangerous chemicals. And all of them have their own specialties and requirements to be respected and to be followed.

The Extent of Internationalization

Globalization of all spheres of today's lives leads to internationalization of all activities. But the extent of that internationalization is sometimes not really visible and is much deeper than it seems to be at first sight. E.g. if a Spanish company, which is a subsidiary of an American enterprise signs a contract with a German plant engineering company for designing of a plant for the Russian client by using a Japanese technology, the deepness of such international cooperation gets more obvious and the complexity of the term more apparent. And if you consider hundreds and thousands of international suppliers of products and services within such projects and their sub suppliers, you can imagine that this is not just "international" but much more "supranational" and "transnational" and really "global".

The Complexity of Sustainability

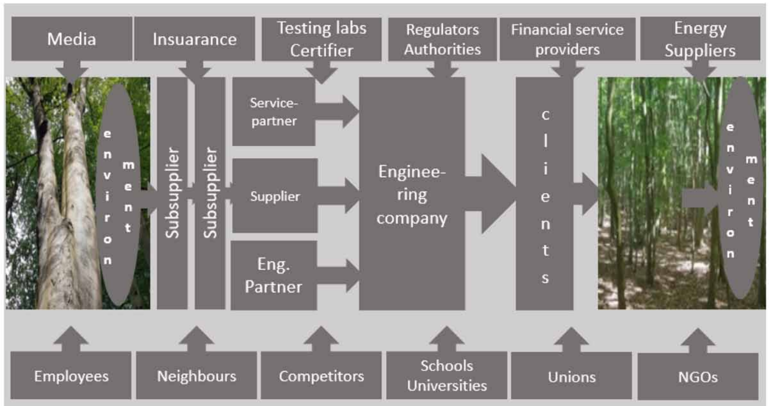
But what is the sustainability? A new modern term? A new idea to become more competitive? Is it just something fashionable? The German dictionary Duden defines the sustainability as “re-growing raw material”[4]. But this approach is now out-of-date, then it has been developed to more complex issue. Yes, it was the origin of the term, back to 1770, when Hans Carl von Carlowitz (1645-1714), a Saxon mining administrator, expressed in his book ”Sylvicultura oeconomica” the idea on cutting down as many trees as it is possible to replant and laid in this way the fundament for the modern sustainability. But nowadays this term comprises much more than renewable raw material. It is about “gentle, attentive and conservative usage of resources”[5]. And this is much more precise, than under “resources” we can understand the most precious resource we have and the one which we have to pay a lot of attention to, especially in this time of digitalization and replacing people through Artificial Intelligence, “the people”. Then behind all changes and all digital advantages we still have people and all the changes have to consider the attitude, the feelings and the desires of those people to get displaced or to have to work with them. The best definition, however, can be found in Gabler Business Encyclopedia, although this one has to be understood in the right way. There the term of sustainability addresses the ability of being “profitable in long-term”[6]. What does it mean: profitable? What profitability do they speak about? How does it affect our lives? It is about profitability for all and each of us? It is almost a philosophical term and can be approached in such an abstract way and it is not just about tomorrow. Is it about our future as parents, children, friends, population and as a mankind and even much more –it is about whole planet and lots of generations behind us. This term is on a global scale and revels the issues that are much further and much deeper than most of us are used to think, but at the same time have to be started now. It is about active change, it is about ethics, it is about another culture, about being flexible and open for the new!

The Importance of Engineering Companies for Achieving the Sustainable Goals

Every branch and every company have to provide their own contribution for the better future. And there is no difference whether you work on a global or local scale, whether the company is a small or a multinational one, whether you work in manufacturing, politics, education, or medicine.

In this chapter the attention is paid to mechanical manufacturing and plant engineering companies. And the reasons for it is not the amount of companies in engineering business in Germany, and their financial strength to deal with the

Figure 1. The complexity of stakeholder-relationships with an engineering company



issue of sustainability, but in their influence of different stakeholders and enormous potential they bring to push forward the issue of sustainability. All manufacturing and especially plant engineering companies act in three roles: firstly, as companies with their own structures, processes and targets, secondly, as innovators of new technologies for other companies - usually their clients – producing companies that buy new sophisticated and innovative technology for the next 25-30 years, and thirdly, as "multiplicators" – recipients of possible new innovations from their suppliers – smaller manufacturing companies of different equipment with their know-how and their inventions in order to become more efficient, more innovative and more competitive. These three categories can be projected from plant engineering companies to different equipment manufacturing companies that all of them to different scales, act in all those functions and have different subcontractors and suppliers on one side and clients on the other side, who in their turn are also suppliers and clients for other at the same time[7].

Plant engineering as well as equipment manufacturing companies act as pushers and advancers of foreign innovative technologies. Apart from those three roles most of these companies are economic subjects that act in a global scale, and therefore their solutions and decisions might affect different stakeholders throughout the world. Furthermore, the networking they bring through their activities, clients, different suppliers with unbelievably long supply chains and other different stakeholders, like financial institutions, accreditation and norming bodies, testing centers, laboratories, but also competitors, as well as educational sector, neighborhood and the whole community is so complex, huge and diverse that it makes possible to reach almost everyone in a society.

The challenge of this problem and the aims of this article are:

1. to find out a frame and reasons for challenges and problems plant engineering and manufacturing companies deal with while working globally
2. to work out consequences of existing trade barriers for global business and how these affect the issue of sustainable business
3. to find the way how to tackle the problem of existing trade barriers on a holistic and systemic manner by identifying the areas of technical compliance and stages of a project where these have to be applied
4. to find the way for more efficient way of dealing with technical regulation and regulatory compliance aspects in plant engineering and equipment manufacturing business and all the requirements on the global scale for international and global working businesses
5. to find out ways to contribute to more Sustainability by abolishing trade barriers and by considering the existing 17 Sustainability Development Goals

In order to provide qualitative and demanding research, considering the need of modern businesses and society within environmental boundaries need the whole methodical approach has to be systemic, holistic, keeping in mind different issues, stakeholders and aspects. For different questions however, different methods can be used:

- Interviews with companies regarding their understanding of the problems and challenges
- Literature review on the topic of sustainable development and sustainability regarding businesses
- Observing the actions of global acting companies

BACKGROUND: THE STATUS QUO OF CHALLENGES AND PROBLEMS IN INTERNATIONAL SALES OF TECHNICAL PRODUCTS

Our recent research[8] focused on finding out the reasons for time- and cost exceedance while working on large scale industrial projects, as those problems are considered to be the most usual ones and the most crucial for the branch to deal with. A lot of researchers and practitioners are trying to find ways to keep the project timely and costly within the frame. Within a project team there some members responsible for this issue: the project manager and schedule planner. Apart from them every specialist from every department and engineering division has his/her time- and cost budget to be allowed. And still this problem seems not to be under control and especially be a huge challenge while doing business abroad.

Different answers were given by project managers and other specialists involved, often emphasizing other specifics and unknown characteristics and requirements of that new foreign country. Very often also customs authorities and supervising bodies are blamed for all delays, because of questioning everything, and requiring more documentation and additional papers that would be not common before. Also, certain colleagues and persons in the projects within the company matrix or on the side of suppliers and clients seemed or at least assumed to be a reason for arisen problems with different stakeholders. Some of the delay causes seemed to lie in misinterpretation of contract details. Interesting is the fact, that although both parties are always working hard on all formulations and precise wording in contracts, they either understand the same issue completely differently or don't understand the whole picture of the issues in the contract. By putting into contract phrases like "fulfilling all the normative and regulatory requirements" the one party might triumph, because of supposedly the one side having to pay attention to every regulation, whereas the other side conceives that nothing concrete is given, so they can decide which regulation would be preferred to be considered and paid attention to and which not.

But all these answers don't reveal the exact challenging issues but show the results of a real problem behind them. And this one is "not knowing", "ignoring" or bad knowledge of regulatory and normative requirements of the target country. And often the involved don´t understand that their answers are not the roots and therefore look for answers in the wrong place by arguing with suppliers, clients, authorities and other stakeholders trying to prove their being right and trying to explain their point of view.

Recognizing the problem in differences in normative requirements very often employees don't want to work on such issues because of felling not responsible for it. And indeed, the topic of regulatory and normative requirements is a very interdisciplinary one. It is between the economics, and technology, Quality Management, legal issues and projects management. But usually there is no one in a company who would work and feel comfortable with such different aspects. Therefore it is important for understanding to offer a systemic and holistic approach: from the general – to the specific and backwards to other abstract issues, from business-related topics – to the research-relevant issues, from customer´s and client's point of view to authorities and society´s, from economy – through engineering - to social issues, keeping always a task of efficient technical and business on one side and environmental targets, as well as the process of vanishing of any boundaries in focus[9].

COMPLEXITY OF TECHNICAL REGULATIONS IN MECHANICAL AND PLANT ENGINEERING BUSINESS

The topic of compliance has become very popular and important while doing business not only in any economic sphere but also in health industry, educational and social fields. It started with ethical issues to be part of every contract and a kind of self-declaration published on every website and started to include more and more adjacent areas. We can identify classic fields like code of conduct, discrimination, corruption, misuse, money-washing, cartel, and acceptance of presents. And there are some new field which have developed to the area of compliance like environmental protection, data protection, export control, IT security, Risk management, transparence and business ethics. All of them have to do with some requirements set up in different regulations and laws. But if we speak about engineering business there is one more very important and special for this branch filed -technical compliance. Technical compliance similar to all other compliance topics refers to conformity of a product or services with requirements and regulations of technical kind. To comply with all those technical regulations, it is important to identify all the requirements which are important to keep in mind and to follow and to identify all those project or process steps in which these requirements occur. And to success it is important to implement the active use of them from the very beginning and to exercise long-sighed activities in this direction.

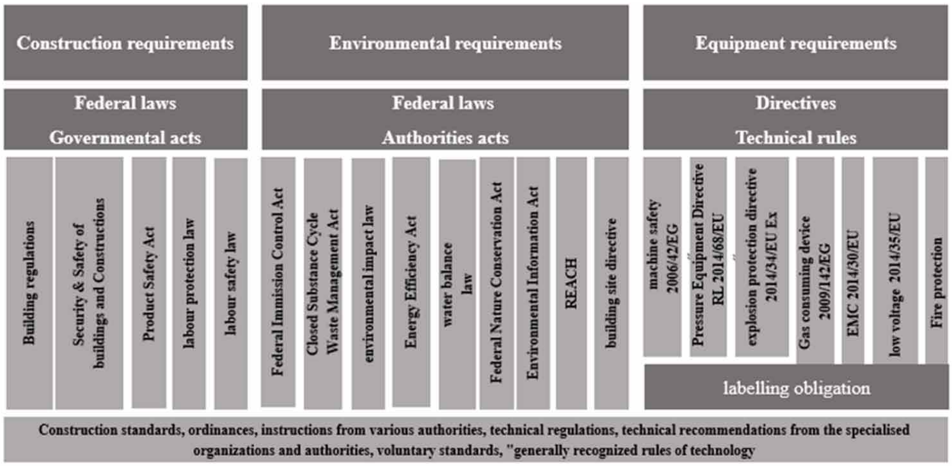
A holistic and systemic approach is inevitable to understand the whole picture and to better analyze the possible challenges and fields to be paid attention to. All normative-regulatory documents of every kind can be divided into 3 main parts:

1. Requirements to engineering processes
2. Requirements to processes referring industrial safety and environmental protection
3. Requirements to equipment itself

Requirements to engineering processes comprise federal laws and governmental resolutions and refer to such issues as Town and Country Planning Code, Code for safety of buildings and constructions, different resolutions for workplace, prevention of accidents, dangerous substances, biological substances, personal protective equipment, also Equipment and Product Safety Act, Labour Protection Law, Occupational Safety Act.

Some federal laws and resolutions of supervising bodies regulate the activities regarding industrial safety if companies deal with projects in chemical, petrochemical, metallurgical, pharmaceutical and oil- and gas industries. Moreover, Federal Immission Control Act, Federal Emission Protection Law, Closed Substance Cycle

Figure 2. The overview of possible requirements and regulations in Germany



Waste Management Act, Refuse Disposal Act, Environmental Impact Assessment Act, Renewable Energy Law, Water Resources Act, Federal Nature Conservation Act, Environmental Information Law, REACH-Resolution[10], Construction Site ordinance[11].

All the requirements to separate equipment are consolidated in different directives and technical regalements according to the specifics of a particular device. The purpose of those directives is to ensure a common safety level in different technical products placed on the market or put in service in all member states and to ensure free movement within the European Union. The main issue behind all these regulations is not to prohibit, restrict or impede the placing on the market or putting into service in their territory if complies with that particular Directive. The most common directives in Europe are Machinery Directive[12], the Pressure Equipment Directive (PED)[13], The ATEX Directive[14], Measuring Instrument Directive[15], Electromagnetic Compatibility[16] and low voltage Directive[17] and fire protection Directive. These directives have general character and are specified in innumerable norms for building, constructing, manufacturing, testing, measuring, decrees and instructions from different authorities, recommendations of specialized organizations, optional standards and the so-called acknowledged rules of technology[18].

To prove the compliance with certain directives some testing and certifying procedures have to be undergone: depending on the type of equipment and area for further use it can be done by specialists of the manufacturers themselves or by authorities- specialized and accredited institutions of that particular country where the product is meant to be used or put into operation. After successful testing manufacturers and those responsible for introduction onto the market are allowed to mark the product according to the fulfilled directive. This marking is used also as a marketing instrument to prove the compliance of the product with the legal, governmental or any other compulsory or optional requirements.

In our global economy lots of companies are working in different markets on a very international level. The drawback of this global activities for manufacturers and for their clients as well are those different rules or sometimes just the number of different directives to be considered. And it is not only the load of huge and immense work to get the knowledge of different approaches and to implement them in their processes but also the number of different authorities that have to test, to supervise, to audit, and in the end to give their approval and permission for manufacturing of specific equipment and for placing them onto that particular market. The main idea of providing an independent verification of compliance with standards related to Safety, performance, reliability, inter-operability and competence is absolutely agreeable and desired by all stakeholders of our society. Also, the procedures of testing the equipment, auditing the manufacturing facilities or testing of the people involved into manufacturing process is the right way to deliver a holistic approach to the issue of certifying of the equipment.

The weak point for the whole industry and the whole society is the number of different certification schemes and different authorities[19].

Almost every country has its own system, its own standards to be complied with, its own verification bodies, its own laboratories and its own procedures. If we take just such a small area if Directive as "Equipment for use in Explosive Atmospheres", there are lots of different international normative requirements, like EN Norms in Europe, CSA and NEC in Canada, GOST –in Russia and lots of CIS countries, JIS Standards in Japan, NEPSI Standards in China, IEC and ISO-Standards on international level[20]. Alone in the USA there is a bunch of different standards which sometimes differ from one federal state to another: UL-, FM-, ANSI, ISA-Standards. According to all these standards there are different certification systems in each country or region of the world[21]. All this leads to a number of certificates to be issued just for one product, for example[22].

It is not only the time but also the money that is behind all such procedures. And the money is not just paid by manufacturers only but in the end by all of users of the equipment and the whole society. If we consider the aspect of sustainability a huge misbalance is obvious at the first sight: the same testing of equipment by different authorities causes huge environmental air pollution through hundreds of audits, waste of material by producing thousands of examples for testing only.

Despite such deep internationalism in mechanical engineering we still have hundreds of different standardization systems and different norms for the same products in the same application[23]. Sometimes the norms might differ slightly, sometimes they are absolutely the same, sometimes manufacturers have to adopt their products to change them to meet the requirements of the country-destination, sometimes it is only the wording and nothing substantially different behind the local standard. But in any case, to fulfill the requirements manufacturers have to subject their products to certain tests executed by different laboratories and certification centers of the target country. To get the required approval label the products have to be delivered to the accredited laboratory and to let auditors from those laboratories, certification centers and surveillance bodies to supervise production facilities and quality of processes and products on their manufacturing sites located at different places in the world. This results in hundreds of repeated tests, which don´t make the products safer, but cause huge amount of additional costs by manufacturers and therefore lead to the increase in price for the product. Moreover, the necessity to test the products and manufacturing procedures leads to enormous environmental burden through huge logistic challenges. But at the same time the progressing digitalization of engineering, commissioning and operating processes requires 100% of compatibility and substitution of different components to enable the desired transferability of information and characteristics. With the Fourth Industrial Revolution we almost "jump" on a new level of dependence and connectedness between different devices and different stakeholders. And this requires standardized approach in lot of technical areas.

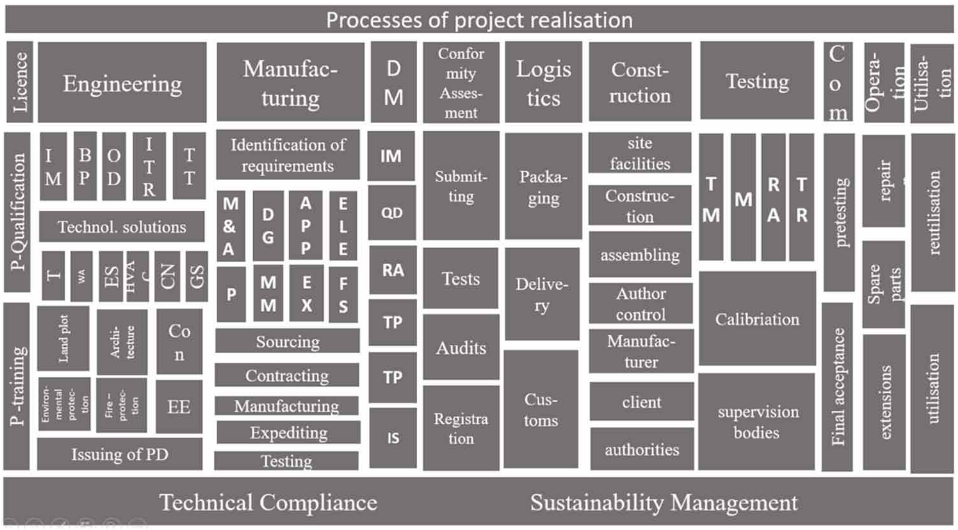
SOLUTIONS AND RECOMMENDATIONS 1: THE STEP-BY-STEP PROCESS OF ABOLISHMENT. WHAT HAS TO BE DONE?

The process of abolishment is a long strategic process, which needs involvement of all parties and a deep commitment to it and complete understanding of advantages. There is a number of organizations that has been working for years to ease barriers to ease, and there are a lot of countries joining together to promote trade and mutual economic benefits. The most important agreement General Agreement on Tariffs and Trade (GATT)[24] should encourage free trade by regulating and reducing tariffs and by providing a forum for resolving trade disputes and the initiative has achieved substantial reductions in tariffs and quotas[25]. But the scale in globalization of modern businesses has become much larger and the agreement doesn´t cover all aspects of modern trade.

The most important organization that encourages global commerce and lower trade barriers, and therefore enforces international rules of trade is the World Trade Organization[26].

But apart from trade tariffs there is another important issue in trading – standardization of products and services, regulation of markets, market surveillance. Also, these problems are addressed by international organizations, like UNECE, that

Figure 3. The complexity of process steps in plant engineering business



promotes the use of standards by policy-makers and business as a tool for reducing technical barriers to trade.

Of course, each medal has two sides and there will be groups of individuals who might see only disadvantages in a common approach to technical regulation, emphasizing the importance of autonomy, originality and specialty of different issues not to be "swept under the carpet". In this case it is important to continue a dialogue and to investigate all possible ways for mutual understanding and all desired paths towards a common goal.

The first step to the abolishment of trade barriers is harmonization of the existing standards. Harmonization can be provided by international standards, which are already worked out by expert groups and can be applied to national regulations in different markets. Harmonization allows to decline the need to customize every product and to retest products at different local nationally accredited laboratories. To achieve a common and by all sides acceptable goal regulatory authorities of different countries have to work together to identify common requirements and a common approach to the processes of conformity assessment and testing the compliance with the required standards.

In order to enable for all manufacturers easier procedures for global trading, to reduce the costs for products due to repeated testing and rerun audits and to contribute to cleaner environment some steps have to be taken:

a) Identification of various fields to be (un)-regulated.

It is important to understand in what areas of economic activities a supervising process and control activities by an authority is important. As stated before it can be not only different products themselves-from machinery till food and cosmetics, but also the processes (e.g. manufacturing process, the process of construction, calculating, commissioning, testing activities) and the persons according to the required skills to fulfill the required commitments. It is also crucial to understand the differences between various application fields and their specifics to be implemented into the norms.

b) *Identification of differences in approaching to those regulations in different countries and economic unions.*

To harmonize the approach and the process one should at first identify the differences to check whether the compatibility is possible in general and if yes, in what way. If all procedures to approach the regulation are unified, it is easier for those who apply and those who use the product.

c) Identification of stakeholders (private companies and international institutions) to work together on the issue

Every company and every activity field have various stakeholders and those might be of very opposite views and with different reasons and ideas. It is important to consider all of them: suppliers, and their suppliers, clients, all partners for dif. Components or services, but also the political structure in a society, the authorities and regulators, certification bodies and testing centers, financial organization, that invest money in a business, but also the neighborhood, the pupils at schools and students at universities, elder generations and young ones, men and women, and of all international background and personal views.

d) *Harmonization of standards for the same products and in the same applications*.

If the application and the nature of product are the same, the same international standards have to be applied. Harmonization and moreover using unique standards for all economic participants will influence enormously the sustainability impact for the whole society. Such attempts have been made of some years by different institutions, like IECEx system, whose motto is to provide one certificate for one product in the whole world. Sound like utopia? Why not? Lots of attempts to harmonize the standards are executed by UNECE, esp. Working Group 6. New attempts are being taken at the moment by Eastern Committee of Eastern relationships with the

Russian RSPP. The aim is to harmonize as many as possible Technical regalements of EAEU with that of Europe.

e) Multilateral agreement about recognition of international tests and audits done by different laboratories, certification centers and surveillance authorities.

A huge topic is the recognition of the results of metrological testing. We have all one metric in Paris to be used as a model for all other laboratories, which are accredited to be such. If the accreditation was successful, this proves that the personal can understand the measuring results in any country. But why do we have to execute the research to prove the opposite.

SOLUTIONS AND RECOMMENDATIONS 2: WHERE CAN ALL THE REQUIREMENTS BE APPLIED?

There are two approaches to application of different requirements and two paths to go.

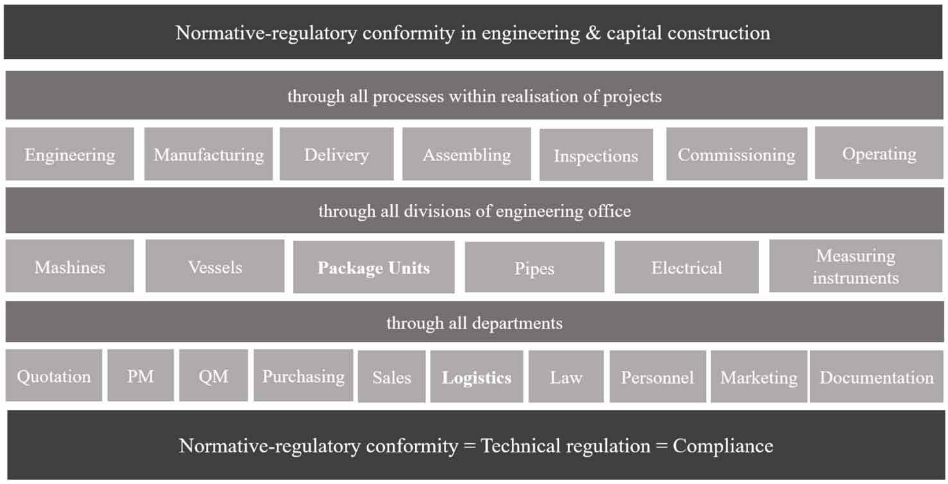
The first path – project oriented. Speaking about engineering of a product or a plant at first different processes of the project realization have to be considered. These comprise the engineering itself, which consists of different parts like architectural, electrical, mechanical, according to fire protection and safety declaration. Depending on the depth of engineering it can incorporate basic or detailed engineering. The manufacturing of different products is also subject to specific requirements of technical regulation as well as testing, documentation, packaging, logistics, and the whole supplier chains. The activities on the building site as construction, welding, fitting, installation, erection, assembling succumb also to specific requirements. Furthermore, commissioning with all the acceptance and approval testing through manufacturers, projects owners or authorities play an important part. But also, later after commissioning and launching the product or the plant and operation itself, there are different regulations to follow.

The second path – department oriented. Normative conformity refers not only to process of project realization but also directly to all divisions of engineering department, as for all kind of equipment there are specific directives and standards to fulfil: machines, apparatus, Package Units, piping, electrical, instrumentation and control and measuring equipment.

But also, all other departments of a manufacturing or engineering company have to deal with different regulations: quotation department, Project management, Quality Management, Purchasing, Law, Personnel, Marketing, and Documentation.

The above-mentioned shows that the vertical as well as horizontal structures of any company dealing with production of goods have to deal at certain stages within

Figure 4. Different Paths and approaches to application of requirements



their structures and processes with certain requirements related either directly to them or indirectly to the whole activity. It may be called in different ways, like normative-regulatory compliance, technical regulation, technical compliance, but it affects everyone, at every stage and in every region and country of the world.

General principles of the international regulation procedures can be applied to different types of regulatory processes and various types of equipment, products and services from other fields than industrial mechanical engineering.

SOLUTIONS AND RECOMMENDATIONS 3: FACTORS FOR SUCCESSFUL REALIZATION OF PROJECTS.

Technical compliance of all products and processes should be an essential part of every project Management. To achieve it, it is important to check normative-regulatory requirements before signing a contract and in every project and every branch. "To check" means not only to find out what regulations have to be applied but to understand to the core of each particular law, norm and standard what it means and how much effort one may need to fulfill them. And this is a very difficult task because the complexity of all the equipment first and then of all the regulations and their connectedness with other issues are of such high level that it is almost impossible to "check" without deep analysis. This one might be done by specialized companies but usually at this stage the importance of such deep check is underestimated which leads to "surprises" at a later stage.

It is important to keep all the costs in mind not only for different certification and testing procedures but also for different approaches and educating the suppliers and colleagues according to new requirements. And this again is very ambiguous and difficult to grasp without professional support.

Logical allocation of responsibilities is another very important issue. It is important to keep the main target in mind and not to shift some responsibilities from one side to another just to minimize the number of things to do for yourself. It is not about the number of activities that counts, but the right approach from the right side. Sometimes a client might insist on the supplier to execute the calibration of all measuring instruments and the supplier might perform this activity. But it is still not the logical decision and a way, because it is much easier for the client to do this procedure on its own as he (the client) is sure to have already a contract with an institute for measuring tests, the one, that is familiar with the equipment and with the whole process at this very manufacturing sight and because it might be very much cheaper for the client to order such measuring tests because of being a "national" client and because of all discounts the client has. And it is not only about financial savings but also time: as familiar ways make the process shorter and more convenient.

Audit and expediting of subcontractors are a very important step in all supplier chain management –process. Before auditing it is important to educate the suppliers about different requirements and the ways to fulfill them. Nevertheless, the documentation has to be checked permanently and constantly and clear requirements not only to content, but also to format have to be made.

Regarding future approval and certification process Future oriented selection of measuring instruments and equipment for use in explosive atmospheres

Complex and systemic approach is a very important issue in dealing with different requirements of a project Management. It is essential to see the whole picture and to approach all the requirements considering different issues, different stakeholders and all applied regulation. And this means – identifying and considering all possible risks and looking behind cost savings.

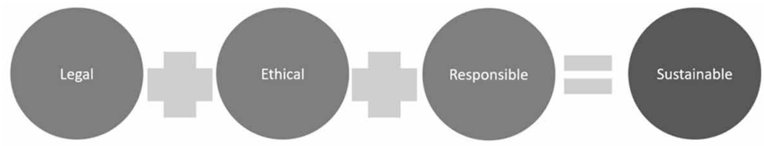
A complex approach can be illustrated with the Russian Matryoshka: one doll doesn´t exist and only if there are some of them, which can be put together to build one whole the whole structure is of value. It is important to identify those several Matryoshkas, to see them separately, but in the end to put them together. In our five-dolls Matryoshka set we identify following requirements of a company:

1) The core competence: the product or service, the know-how, that the company provides.

2) Strategic requirements to become better that the competitors, like Quality Management, Innovation management, knowledge Management, supplier management, sales and marketing.
3) Stakeholder interests: as the most precious resource of every company is their personnel, the staff. And if you treat the staff the way people and you would like to be treated, you might achieve all those targets that were set for you and your company. Such issues as equal rights, safety at work, health protection, compatibility of family and professional lives, qualification, flexible working hours, inclusion are the ones to pay attention to in this Matryoshka.
4) Social Requirements, such as growing and aging population, migration, compliance aspects, ethical issues, information security and justice shape the next level.
5) Above all we have environmental boundaries which are essential for all other layers and which give the whole Matryoshka-Construct the required stability: climate change, plastic disaster, chemical contamination, biodiversity, ozone hole, soil, air and water pollution –are the ones we already surpassed the boundaries and are supposed to find the ways to bring it to acceptable level back.

Figure 5. Matryoshka –model of business requirements and holistic sustainability approach

Figure 6. Components for sustainable business management strategy

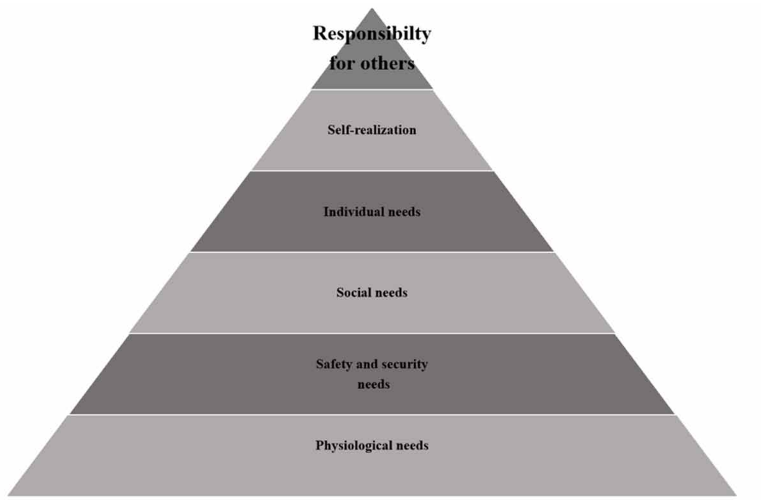


Being flexible and paying attention to different factors underlines the importance of learning continuously. Knowledge management and intercultural competence are other kea issues to achieve success in every business which relies on systemic approach to all information. And other important issues are such obvious ones, that no one pays attention, because it seems too simple and too banal: but there are the most important ones: ability and willingness to communicate with all partners and a real desire to CO-operate: to work together, to solve the problem together, to achieve something together with all involved parties.

Speaking about technical compliance it is also important to understand that these requirements are just a basis for all business activities, it is a legal part and something that is required by authorities, stakeholders and the whole society. Apart from that modern companies should consider ethical issues and be ready to do not just the right things but also more good ones, which is amplified into responsibility. But also, beyond the issue of responsibility there are some natural and social boundaries and the aim of the 21. Century business is to operate within those social and environmental thresholds and do thing that last and therefore form sustainable development.

Apart from the desire of society, political communities and business structure to develop sustainable environment for all activities and to ensure a safe life for further generation, the ambition to achieve all those 17 goals, agreed on in Paris in 2015, is due to lots of people personally. Those “Lots of” are people who achieved their own targets, who are satisfied with their lives and doesn´t matter whether the satisfaction is of financial or just personal kind. There should be another desire than those 5 which were proposed by Abraham Maslow in his paper “A theory of Human Motivation”, issued in 1943 in Psychological Review. After fulfilling all those mentioned hierarchical needs, such as physiological, safety, lobe and belonging, self-esteem and self-actualization people are eager to leave their own mark in society, to keep themselves in mind of others by doing something valuable. This 6. Need might be called as responsivity towards other people. This can be observed by people who have already earned a fortune and can “afford” doing something good for others, like activities of Bill Gates, Elon Musk, and other philanthropists, who spent their time, finance and their power to find new ways to achieve fairer world and to save

Figure 7. Extended Maslow´s Pyramid of needs



people, the planet and generations. But also, by people without such possibilities and opportunities at a small scale, like grandparents helping their grandchildren, or any voluntary work in general and altruistic activities– public help to refugees, to old people, to people in poor countries, volunteering in developing countries, environmental, community and welfare volunteering etc.

FUTURE RESEARCH DIRECTIONS

The issue of sustainability becomes very important not only at educational institutions and politics but also more and more companies pay their attention to the issues as the awareness of society and different stakeholders is growing. Companies in textile industry and in food production industry have recognized the importance of the topic and are active in the field of sustainability in their own corporate structures and in communication of their sustainability targets. The machine manufacturers have also taken up very interesting aspects of sustainability and are actively working on some technological innovations in order to develop innovative resource-saving technologies and production methods. The Blue Competence Sustainability Initiative within German VDMA-Union have adopted a sustainability code. The member companies commit themselves to a responsible use of energy and resources as well as to social responsibility[27].

Only most sustainability issues in mechanical engineering are currently actually focusing on what they do best, developing new technologies that are more cost-effective and more profitable. But this is very one-sided, because the sustainability issue also includes social and environmental aspects, not only the issues required by law, but also the ethical issues society is asking and expecting from business and industry.

The field is so broad and multi-layered that it is necessary to identify various topics in the field of sustainability in mechanical and plant engineering and to find different approaches to the topic in order to point out possible ways forward. It is important that a holistic and holistic approach is guaranteed.

This results in many topics that can be specified in further research:

Sustainability in certain internal company processes, sustainability in the planning of plants, sustainability in the handling of projects in the international plant construction business.

However, various structures can also be examined from the point of view of sustainable development. For example, project implementation structures can be examined in terms of their sustainability theme - from the qualification of the personnel, through project planning, production, delivery to the commissioning of the plants and their operation and utilization. Or even individual engineering trades and independent departments, which can certainly have a number of overarching topics, but also very specific topics that only apply to their departments in quality management, innovation management, knowledge management, etc. can show applicable topics.

With regard to the harmonization of standards worldwide, it is important to take individual steps - starting with small steps. This creates many opportunities to examine the ways of harmonizing certain standards from a technical field, such as machine safety or explosion protection or electrical engineering. It is also possible to differentiate between countries and regions. One can, for example, investigate which possibilities exist to address certain technical requirements of the European Union with other customs unions or economic unions, such as the Eurasian Economic Union.

Another important way to promote sustainability in mechanical engineering is the direct analysis of the reasonable ways forward based on the existing 17 SDGs.

Some other issues are very much linked with the topic of Sustainability which also might be a part of the future research: corporate social responsibility, Supply Chain Management, the social and community impact of different kind pf industrial projects, environmental impact on production management and in general on global sustainable management standards, including existing ones, like Quality Management, Environmental Management and Labor safety.

Speaking about technical barriers it might and should be possible to identify the drivers for implementing sustainable development practices, sustainability in the construction sector but also in civil engineering. The topic moves ever more into the foreground and becomes even the competition advantage[28].

The new requirements require new innovative thinking and new perceptions of the modern targets by formulating new rules to guide the global economy. These new approaches have to be developed, investigated and if suitable to be applicated to the existing structures to abolish inequalities in economic, social and environmental context.

CONCLUSION

Sustainability in mechanical and engineering businesses, including design and construction operations is one of the most significant topics of industrial community of the twenty-first century[29]. There are some ways how harmonization can contribute to Sustainable Development Goals. Herewith some ideas, which can serve as impulses for looking for other and new ways of connecting and influencing each other.

Through existing different technical requirements, it is not possible for export-oriented companies in mechanical and engineering businesses, which work with a huge number of different suppliers and provide products and services to a vast number of international clients in the globalized world to consider different technical requirements and to stay sustainable. Moreover, different technical regulations pull the sustainability issues back and prevent companies in some cases from more sustainable ways of conducting their businesses, therefore it is very important to harmonize standards to reach similar approach and to cut down lots of doubled procedures and to get the same clear and definite platform for mutual cooperation.

1) Through harmonization of standards we can lower the product prices, increase the salaries, and employ more people and therefore contribute to decent work and economic growth of local and international regions.
2) Through clear harmonized requirements we will achieve better competition and more transparency, which accounts for more compliance within sourcing and sales procedure.
3) It will lead to more global opportunities, allow global market access for all manufacturers and therefore contribute to equality of opportunities in different directions and in some cases to abolishment of poverty and hunger.
4) Harmonization leads to more industrial safety through definite compatibility of different products from the whole world and to better nature protection.
5) Through abolishment of technical barriers companies and suppliers can concentrate on the most important issues of developing qualitative and secure product for any country and region and therefore to focus on important issues rather than spending time for finding out differences and paying attention to all the differences that have to be considered while designing a product for a

different market. Its issue can trigger off new capacity and ignite new power for developing innovative products rather than adjust the existing ones to different regulations.

6) By saving time and money from elimination of technical barriers companies and industries might invest it in new infrastructure project, in innovative affordable and clean energy solutions and in development of sustainable businesses and industries which will contribute to cleaner environment, to better education and to more responsible consumption and production in general. In other words, through harmonization of standards and abolishment of trading barriers we can contribute to Sustainable Development of the whole society.

The research on the different issues and approaches to sustainability in mechanical and engineering business should be continued by all professional community who are interested in preserving the planet for future generations. It is a unique opportunity for all manufacturing and engineering companies to take the lead, to take the responsibility and by implementing different aspects of economic, social and environmental sustainability to drive the development of the holistic sustainability culture in the world – according to modern requirements and challenges and within planetary boundaries[30].

REFERENCES

2012. ArchiveB. (n.d.). Retrieved from https://2012books.lardbucket.org/pdfs/an-introduction-to-business-v2.0.pdf

Arnold, M. (2016). Systemische Strukturaufstellungen als neue Methode zur Förderung einer nachhaltigen Entwicklung. *Ökologisches Wirtschaften - Fachzeitschrift, 31*(3), 44.

Cornelis, A., & de Kluyver, K. (2012). *Global strategy*. Oxford, UK: Lardbucket.

Duden. (2018). *Nachhaltigkeit*. Retrieved from https://www.duden.de/rechtschreibung/Nachhaltigkeit

Gabler Wirtschaftslexikon. (2018). *Nachhaltigkeit*. Retrieved from https://wirtschaftslexikon.gabler.de/definition/nachhaltigkeit-41203

Johnson, W. (2017). *Pros & Cons of Global Companies*. Retrieved from https://bizfluent.com/info-7756133-pros-cons-global-companies.html

Klotz-Engmann, G. (2014). *Internationale Normung für Prozess-Sensoren*. Paper presented at the Summit for Microsystem technology, Freiburg, Germany.

Krause, J. (2015). *Regulierung von Investitionsprojekten in Russland*. Wiesbaden, Germany: Gabler Springer.

Krause, J. (2018): Durch Technische Compliance zu mehr Effizienz in der Chlorindustrie. *Vestnik chimičeskoj promyšlennosti,* (102), 18-23.

12. Manage. (2007). *Description of Corporate Sustainability, Explanation*. Amsterdam: 12Manage. Retrieved from http://www.12manage.com/ description_ corporate_sustainability.html

MM/ Maschinenmarkt. (2013). *Blue Competence Kodex für Nachhaltigkeit im Maschinenbau beschlossen.* Retrieved from https://www.wiso-net.de/document/ MAMA__381513500

Raworth, K. (2017). *Doughnut Economics. Seven ways to think like a 21st-Cebntury Economist*. London, UK: Cornestone.

VDI. (2012). Maschinenbauer wollen durch Nachhaltigkeit punkten. *VDI Nachrichten*. Retrieved from https://www.wiso-net.de/document/VDIN__522444

Weka Business Medien Gmb, H. (2003). *Internationale Harmonisierung*. Scope. Retrieved from https://www.wiso-net.de/document/SCOP__SCOP200304011823 29142723102918242310211417 1027222423

Wikipedia. (2018). *Nachhaltigkeit*. Retrieved from https://de.wikipedia.org/wiki/ Nachhaltigkeit

Yates, J. K. (2016). Sustainability in engineering design and construction. Boca Raton, FL: CRC Press, an imprint of the Taylor & Francis Group.

ADDITIONAL READING

Anselmann, N. (1991). *Technische Vorschriften und Normen in Europa: Harmonisierung und gegenseitige Anerkennung*. Bonn: Economica-Verlag.

Antuchevičienė, J. (Ed.). (2018). Sustainability in Construction Engineering. MDPI - Multidisciplinary Digital Publishing Institute.

Assmann, H. (2012). *Normen, Standards, Werte - was die Welt zusammenhält. (1. Aufl.)*. Baden-Baden: Nomos. doi:10.5771/9783845239330

Casella, A. (2001). *Product Standards and International Trade. Harmonization through Private Coalitions?* Retrieved from https://www.wiso-net.de/document/ MIND__58595

Göler, D., & Stratenschulte, E. D. (2018). *Norm- und Regeltransfer in der europäischen Außenpolitik (1. Auflage.)*. Baden-Baden: Nomos. doi:10.5771/9783845280417

Hänsel, F. (2008). *Zur Formalisierung technischer Normen*. Düsseldorf: VDI-Verlag.

Krauss, J. (2018). Review of Doughnut Economics: 7 Ways to Think Like a 21st Century Economist by Kate Raworth. 2017. White River Junction, VT: Chelsea Green Publishing. 320 pages, ISBN 978-1 6035-8674-0 Cloth ($28.00). *Journal of World-systems Research*, *24*(2), 452–457. doi:10.5195/JWSR.2018.854

Messner, S. (2014). *Tod der Harmonisierung?* Retrieved from https://www.wiso-net.de/document/ABAU__066065085090069073084095201402141533180005

Michalas, N. (2003). *Methodik zur Gestaltung von nachhaltigen Nutzungskonzepten im Maschinen- und Anlagenbau*. Aachen: Shaker.

Rese, M. (1993). *Technische Normen und Wettbewerbsstrategie: Wettbewerbsstrukturelle Implikationen einer Harmonisierung (sicherheits-) technischer Vorschriften, dargestellt am Beispiel der Aufzugsindustrie*. Berlin: Beuth.

Schellberg, K. U. (1992). *Technische Harmonisierung in der EG: Ökonomie und Politik der gegenseitigen Anerkennung, Rechtsangleichung und Normung*. Frankfurt am Main: Lang.

Schmauder, M. (2010). *Schlussbericht - Nachhaltigkeit als Innovations- und Unternehmensstrategie im Maschinenbau: Ergebnisse aus dem Forschungsprojekt "Untersuchungen zur Integration von Nachhaltigkeitsaspekten in Innovationsprozesse im Maschinen- und Anlagenbau Deutschlands (INAIN)", Laufzeit: 01.09.2008 bis 31.08.2010*. Dresden: Technische Universität Dresden, Fakultät Maschinenwesen, CIMTT Zentrum für Produktionstechnik und Organisation.

Sivakumar Babu, G., Saride, S., & Basha, B. M. (2017). *Sustainability Issues in Civil Engineering*. Singapore: Springer. doi:10.1007/978-981-10-1930-2

KEY TERMS AND DEFINITIONS

Engineering Companies: Companies creating new industrial plants by designing the layout, choosing the right technology, calculating and planning the right equipment for the processes and given raw materials.

Harmonization of Norms and Standards: Bringing different regulations of different countries, unions and regions to the same or similar meaning by eliminating huge differences and misunderstandings.

International Business: Company´s activities in selling and buying goods or services for/from different countries.

Standardization: The process of making things of the same kind, including products and services, have the same basic features and the same requirements.

Sustainability: The issue of being able to continue over a period of time and consider requirements and concerns of social, economic and environmental kind of every generation.

Technical Barriers: Some obstacles for technical goods and services that prevent countries and companies from delivering or starting activities in a particular region.

Technical Compliance: Confirmation with particular requirement of technical kind or and for technical product and service, the act of obeying a particular technical rule, norm, standard or law and of acting according to the requirements for technical products.

Technical Regulation: An official authority rule or the act of controlling market introduction and putting into operation of technical devices.

ENDNOTES

1 Johnson, 2017.

2 Cornelis A. et al., 2012.

3 Krause, 2018.

4 Duden, https://www.duden.de/rechtschreibung/Nachhaltigkeit

5 Wikipedia, https://de.wikipedia.org/wiki/Nachhaltigkeit.

6 Gabler Wirtschaftslexikon, https://wirtschaftslexikon.gabler.de/definition/nachhaltigkeit-41203

7 The supply chains of every manufacture and especially of every plant engineering company is very complex, long and multi-chained.

8 By using the method of partly-standardized interview forty-four engineering and manufacturing companies were interviewed at Achema Exhibition in on the 19.06.2018.

9 Arnold, 2017.

10 REACH stands for Registration, Evaluation, Authorisation and Restriction of Chemicals and addresses the production and use of chemical substances and their potential impacts on both human health and the environment.

11 In Germany it is 92/57/EWG

12 Directive 2006/42/EG of the European Parliament and of the Council of 17 May 2006 concerning machinery and certain parts of machinery.

13 Directive 2014/68/EU replaced the former Directive 97/23/EC, sets standards for the design and fabrication of pressure equipment. Pressure equipment

include different types of pressure vessels, which might be steam boilers, heat exchanger, reactors, but also piping and safety valves and other components and assemblies subject to maximum pressure of more than 0,5 bar.

[14] The term “ATEX” comes from the French “Atmospheres Explosibles” and is used for the equipment and systems, electrical and non-electrical, in an environment with an explosive atmosphere.

[15] The Directive 2014/32/EU covers such measuring instruments as water meters, gas meters, active, electrical energy meters, heat meters, taximeters, dimensioning systems, exhaust gas analysers and is supposed to harmonise some aspects of legal metrology within the EU.

[16] The Directive 2014/30/EU.

[17] The Directive 2014/35/EU.

[18] In German “Allgemein anerkannte Regeln der Technik“

[19] Krause, 2015.

[20] Klotz-Engmann, 2014.

[21] Weka Business Medien GmbH: “If, however, there is an ocean in between, as is the case with North America and Europe, then people, currencies and even norms will find it much more difficult to come together. Which is why, for example, electric cables have suffered all over Europe, but can cause the greatest difficulties in America”.

[22] Some German manufacturers for measuring equipment claim to need more than 20 certificates for just one sensor to be delivered to different countries and markets.

[23] In Europe EU-Directives, in Japan –JISHA and JIS –Standards, in the USA –OSHA, ANSI, UL, NFPA, in Canada –CCOHS, CSA, in Brazil – NR, in Russia- TR EAEU, in China –CCC etc.

[24] The GATT-Agreement was first signed by 23 nations in 1947.

[25] 2012 Book Archive, S. 159, https://2012books.lardbucket.org/pdfs/an-introduction-to-business-v2.0.pdf

[26] WTO, founded in 1995, is based in Geneva and has over 150 members. But also, WTO allows the aggrieved nations to impose counter-tariffs on some politically sensitive products, like it happened in recent months with the reaction to the USA imposing tariffs on imported steel.

[27] Maschinenmarkt, 2013.

[28] VDI, 2012.

[29] Yates, 2016.

[30] Raworth, 2018.

Compilation of References

12. Manage. (2007). *Description of Corporate Sustainability, Explanation*. Amsterdam: 12Manage. Retrieved from http://www.12manage.com/ description_corporate_sustainability.html

2012. ArchiveB. (n.d.). Retrieved from https://2012books.lardbucket.org/pdfs/an-introduction-to-business-v2.0.pdf

Adair, J. (2010). *Six barriers to creative thinking and innovation*. Retrieved January 5, 2019 from http://www.1000ventures.com/business_guide/crosscuttings/creativity_6barriers_ja.html

Adams, R. L. (2017). *10 Powerful examples of artificial intelligence in use today*. Retrieved from http://www.forbes.com/sites/robertadams/2017/01/10/10-powerful-examples-of-artificialintelligence-in-use-today/#39af9a7420de

Aghababyan, A. R., Grigoryan, V. G., Stepanyan, A. Y., Arutyunyan, N. D., & Stepanyan, L. S. (2007). EEG reactions during creative activity. *Human Physiology*, *33*(2), 252–253. doi:10.1134/S0362119707020193

Agnati, L. F., & Fuxe, K. (1984). New concepts on the structure of the neuronal networks: The miniaturization and hierarchical organization of the central nervous system. *Bioscience Reports*, *4*(2), 93–98. doi:10.1007/BF01120304 PMID:6713088

Agnati, L. F., Guidolin, D., Battistin, L., Pagnoni, G., & Fuxe, K. (2013). The Neurobiology of Imagination: Possible Role of Interaction-Dominant Dynamics and Default Mode Network. *Frontiers in Psychology*, *4*. doi:10.3389/fpsyg.2013.00296 PMID:23745117

Agnati, L. F., Guidolin, D., Cortelli, P., Genedani, S., Cela-Conde, C., & Fuxe, K. (2012). Neural correlates to consciousness. The “Hall of mirrors” metaphor describing consciousness as an epiphenomenon of multiple dynamic mosaics of cortical functional modules. *Brain Research*, *1476*, 3–21. doi:10.1016/j.brainres.2012.01.003 PMID:22322150

Agnati, L. F., Guidolin, D., Guescini, M., Genedani, S., & Fuxe, K. (2010). Understanding wiring and volume transmission. *Brain Research. Brain Research Reviews*, *64*(1), 137–159. doi:10.1016/j.brainresrev.2010.03.003 PMID:20347870

Agnati, L. F., Zunarelli, E., Genedani, S., & Fuxe, K. (2006). On the existence of a global molecular network enmeshing the whole central nervous system: Physiological and pathological implications. *Current Protein & Peptide Science*, *7*(1), 3–15. doi:10.2174/138920306775474086 PMID:16472166

Alavi, M., & Leidner, D. E. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. *Management Information Systems Quarterly*, *25*(1), 107–136. doi:10.2307/3250961

Aldridge, A. (1984). *The scientific world view in dystopia*. Ann Arbor, MI: UMI Research Press.

Alkon, P. K. (2002). *Science Fiction Before 1900: Imagination Discovers Technology*. Londres: Routledge.

Alkon, P. K. (2010). *Origins of Futuristic Fiction*. University of Georgia Press.

Allihn, L. (2013). Gen Y. Kinder unserer Zeit. In H. Künzel (Ed.), *Erfolgsfaktor Employer Branding: Mitarbeiter binden und die Gen Y gewinnen* (pp. 17–34). Berlin: Springer-Verlag. doi:10.1007/978-3-642-40535-8_2

Allman, J. M., Tetreault, M. A., Hakeem, A. Y., Manaye, K. F., Semendeferi, K., Erwin, J. M., ... Hof, P. R. (2011). The Von Economo neurons in the frontoinsular and anterior cingulate cortex. *Annals of the New York Academy of Sciences*, *1225*(1), 59–71. doi:10.1111/j.1749-6632.2011.06011.x PMID:21534993

Amabile, T. M. (1996). *Creativity in context*. Boulder, CO: Westview.

American Productivity and Quality Centre. (2018). *APQC's Knowledge flow process framework*. Houston, TX: APQC.

Anderson, B. (2016). *Imagined Communities. Reflections on the Origin and Spread of Nationalism*. London, UK: Verso. (Original work published 1983)

Anderson, M. L. (2007). Massive redeployment, exaptation, and the functional integration of cognitive operations. *Synthese*, *159*(3), 329–345. doi:10.100711229-007-9233-2

Anderson, M. L., Richardson, M. J., & Chemero, A. (2012). Eroding the boundary of cognition: Implications of embodiment (1). *Topics in Cognitive Science*, *4*(4), 717–730. doi:10.1111/j.1756-8765.2012.01211.x PMID:22777798

Andreasen, N. (1987). Creativity and mental illness: Prevalence rates in writers and their first-degree relatives. *The American Journal of Psychiatry*, *144*(10), 1288–1292. doi:10.1176/ajp.144.10.1288 PMID:3499088

Andreasen, N. (2008). Creativity and mood disorders. *Dialogues in Clinical Neuroscience*, *10*, 252–255. PMID:18689294

Andreasen, N. J., & Powers, P. S. (1975). Creativity and psychosis. *Archives of General Psychiatry*, *32*(1), 70–73. doi:10.1001/archpsyc.1975.01760190072008 PMID:1111477

Andrews-Hanna, J. R., Reidler, J. S., Huang, C., & Buckner, R. L. (2010). Evidence for the default network's role in spontaneous cognition. *Journal of Neurophysiology*, *104*(1), 322–335. doi:10.1152/jn.00830.2009 PMID:20463201

Appadurai, A. (2010). *Modernity at Large. Cultural Dimensions of Globalization* (9th ed.). Minneapolis, MN: University of Minnesota Press. (Original work published 1996)

Arensburg, B., Schepartz, L. A., Tillier, A. M., Vandermeersch, B., & Rak, Y. (1989). A reappraisal of the anatomical basis for speech in Middle Palaeolithic hominids. *American Journal of Physical Anthropology*, *83*(2), 137–156. doi:10.1002/ajpa.1330830202 PMID:2248373

Argote, L., & Guo, J. M. (2016). Routines and transactive memory systems: Creating, coordinating, retaining, and transferring knowledge in organizations. *Research in Organizational Behavior*, *36*, 65–84. doi:10.1016/j.riob.2016.10.002

Aritz, J., Walker, R., & Cardon, P. W. (2018). Media Use in Virtual Teams of Varying Levels of Coordination. *Business and Professional Communication Quarterly*, *81*(2), 222–243. doi:10.1177/2329490617723114

Arman, H., & Garbis, C. (1998). Situation Awareness as Distributed Cognition. *ECCE 9: Proceedings of the Ninth European Conference on Cognitive Ergonomics*, 151–156.

Armstrong, M., & Taylor, S. (2014). *Armstrong's Handbook of Human Resource Management Practice*. London: Kogan Page.

Arnheim, R. (1988). *Anschauliches Denken. Zur Einheit von Bild und Begriff* (6th ed.; G. Köln, Ed.). DuMont. (Original work published 1977)

Arnold, M. (2016). Systemische Strukturaufstellungen als neue Methode zur Förderung einer nachhaltigen Entwicklung. *Ökologisches Wirtschaften - Fachzeitschrift, 31*(3), 44.

Aronowitz, S. (1995). *Technoscience and Cyberculture*. Londres: Routledge.

Athanas, C. (2017). Studie zur Candidate Journey: Erfolgreiche Mitarbeiterbindung beginnt im Recruiting. *meta HR Blog.* Retrieved March 31, 2019 from http://blog.metahr.de/2017/01/18/studie-zur-candidate-journey-erfolgreiche-mitarbeiterbindung-beginnt-im-recruiting/

Austin, J. R. (2003). Transactive memory in organizational groups: The effects of content, consensus, specialization, and accuracy on group performance. *The Journal of Applied Psychology*, *88*(5), 866–878. doi:10.1037/0021-9010.88.5.866 PMID:14516250

Baddeley, A. D. (1986). *Working Memory*. New York, NY: Oxford University Press.

Baddeley, A. D. (1992). Working Memory. *Science*. *New Series*, *255*(5044), 556–559. PMID:1736359

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, *4*(11), 417–423. doi:10.1016/S1364-6613(00)01538-2 PMID:11058819

Baheti, R., & Gill, H. (2011). Cyber-physical systems. In The impact of control technology: Part 3: Cross cutting research directions. New York: IEEE Control Systems Society.

Bailin, S. (1988). *Achieving extraordinary ends: An essay on creativity*. Boston: Kluwer Academic. doi:10.1007/978-94-009-2780-3

Balla, B. (1987). Kultur als Daseinssphäre von Knappheitsbewältigung. In W. Lipp (Ed.), *Kulturtypen, Kulturcharaktere. Träger, Mittler und Stifter von Kultur* (pp. 241–256). Berlin: Reimer.

Banks, M. (2007). *Using Visual Data in Qualitative Research*. London, UK: Sage. doi:10.4135/9780857020260

Barbot, B., Tan, M., & Grigorenko, E. L. (2013). The Genetics of Creativity: The Generative and Receptive Sides of the Creativity Equation. In O. Vartanian, A. S. Bristol, & J. C. Kaufman (Eds.), *Neuroscience of Creativity*. Cambridge, MA: MIT Press. doi:10.7551/mitpress/9780262019583.003.0004

Barbrook, R. (2007). *Imaginary futures – From thinking machines to the global village*. Londres: Pluto Press.

Barnes, J. (Ed.). (1984). *The Complete Works of Aristotle* (Vols. 1-2). Princeton, NJ: Princeton University Press.

Baron-Cohen, S. (2006). The biology of the imagination: how the brain can both play with truth and survive a predator. In R. H. Wells & J. McFadden (Eds.), *Human Nature: Fact and Fiction*. London: Continuum International Publishing Group.

Baudrillard, J. (1982). *Der symbolische Tausch und der Tod*. München: Matthes und Seitz.

Bdnews24. (2018). *Fourth industrial revolution is real, present in Bangladesh: Foreign minister*. Retrieved from: https://bdnews24.com/economy/2018/11/13/fourth-industrial-revolution-is-real-present-in-bangladesh-foreign-minister

Beachcroft-Shaw, H., & Ellis, D. (2017). Social Marketing to Achieve Sustainability. In Z. Fields (Ed.), *Collective creativity for responsible and sustainable business practice* (pp. 296–314). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-1823-5.ch016

Beaney, M. (2010). *Imagination and Creativity* (2nd ed.). Open University.

Beaty, R. E., Benedek, M., Kaufman, S. B., & Silvia, P. J. (2015). Default and executive network coupling supports creative idea production. *Scientific Reports*, *5*(1), 109–164. doi:10.1038rep10964 PMID:26084037

Beaty, R. E., Benedek, M., Silvia, P. J., & Schacter, D. L. (2016). Creative cognition and brain network dynamics. *Trends in Cognitive Sciences*, *20*(2), 87–95. doi:10.1016/j.tics.2015.10.004 PMID:26553223

Beaty, R. E., Chen, Q., Christensen, A. P., Qui, J., Silvia, P. J., & Schacter, D. L. (2018). Brain networks of the imaginative mind: Dynamic functional connectivity of default and cognitive control networks relates to openness to experience. *Human Brain Mapping*, *39*(2), 811–821. doi:10.1002/hbm.23884 PMID:29136310

Beaty, R. E., Silvia, P. J., & Benedek, M. (2017). Brain networks underlying novel metaphor production. *Brain and Cognition*, *111*, 163–170. doi:10.1016/j.bandc.2016.12.004 PMID:28038366

Beck, C. (2012). Personalmarketing 2.0 - Personalmarketing in der nächsten Stufe is Präferenz-Management. In C. Beck (Ed.), *Personalmarketing 2.0. Vom Employer Branding zum Recruiting* (pp. 9–70). Cologne: Luchterhand.

Beck, U. (1999). *Was ist Globalisierung?* (6th ed.). Frankfurt am Main, Germany: Suhrkamp.

Beghetto, R. A., & Kaufman, J. C. (2007). Toward a broader conception of creativity: A case for mini-c creativity. *Psychology of Aesthetics, Creativity, and the Arts*, *1*(2), 73–79. doi:10.1037/1931-3896.1.2.73

Belk, R. W. (1988). Possessions and the Extended Self. *The Journal of Consumer Research*, *15*(2), 139–168. doi:10.1086/209154

Benjamin, J., Li, L., Patterson, C., Greenburg, B. D., Murphy, D. L., & Hamer, D. H. (1996). Population and familial association between the D4 dopamine receptor gene and measures of novelty seeking. *Nature Genetics*, *12*(1), 81–84. doi:10.1038/ng0196-81 PMID:8528258

Bhalla, V., Dyrchs, S., & Strack, R. (2017). *Twelve forces that will radically change how organizations work*. Retrieved from https://www.bcg.com/publications/2017/people-organization-strategy-twelve-forces-radically-change-organizations-work.aspx/

Bickerton, D. (2003). Symbol and structure: A comprehensive framework for language evolution. In M. H. Christiansen & S. Kirby (Eds.), *Language Evolution*. Oxford, UK: Oxford University Press. doi:10.1093/acprof:oso/9780199244843.003.0005

Blausen.com staff. (2014). Medical gallery of Blausen Medical 2014. *WikiJournal of Medicine*, *1*(2). doi:10.15347/wjm/2014.010

Bleys, B., Defloor, B., Van Ootegem, L., & Verhofstadt, E. (2018). The environmental impact of individual behavior: Self-assessment versus the ecological footprint. *Environment and Behavior*, *50*(2), 187–212. doi:10.1177/0013916517693046

Bloomfield, M. [Creative Being]. (2018, October 1). *Can you unlock your creative genius?* [Video file]. Retrieved June 1, 2019 from https://www.youtube.com/watch?v=qbV_c3gyoiw&feature=youtu.be&fbclid=IwAR0EOxQ-P0agFY-NIYfzI5rrAajI5aLKOGB79vPLyuBUdUzLNcEYe4A-ZRs

Boden, M. A. (2004). *The creative mind: Myths and mechanisms* (2nd ed.). London: Routledge. doi:10.4324/9780203508527

Boden, M. A. (2006). *Mind as machine: A history of cognitive science*. Oxford, UK: Clarendon Press.

Boehm, G. (1994). *Was ist ein Bild?* (4th ed.). München, Germany: Fink.

Boehm, G. (2007). *Wie Bilder Sinn erzeugen. Die Macht des Zeigens*. Berlin, Germany: University Press.

Boesch, C., & Boesch, H. (1984). Mental maps in chimpanzees: An analysis of hammer transport for nut cracking. *Primates*, *25*(2), 160–170. doi:10.1007/BF02382388

Bogen, J. E., & Bogen, G. M. (1969). The other side of the brain III: The corpus callosum and creativity. *Bulletin of the Los Angeles Neurological Society*, *34*, 191–220. PMID:4902873

Bogen, J. E., & Bogen, G. M. (1988). Creativity and the corpus callosum. *The Psychiatric Clinics of North America*, *11*(3), 293–301. doi:10.1016/S0193-953X(18)30481-7 PMID:3067226

Bogenrieder, I. (2002). Social Architecture as a Prerequisite for Organizational Learning. *Management Learning*, *33*, 197-212.

Bogin, B. (1999). *Patterns of Human Growth* (2nd ed.). Cambridge, UK: Cambridge University Press.

Boschma, R. A. (2005). Proximity and Innovation: A Critical Assessment. *Regional Studies*, *39*(1), 61–74. doi:10.1080/0034340052000320887

Boss, J. A. (2015). *THiNK: Critical thinking and logic skills for everyday life* (3rd ed.). New York, NY: McGraw-Hill Education.

Botsman, R., & Rogers, R. (2010). *What's mine is Yours. The Rise of Collaborative Consumption. How Collaborative Consumption is Changing the Way o Life*. New York: Harper Collins UK.

Bourdieu, P. (1977). *Outline of a Theory of Practice*. New York: Cambridge University Press. doi:10.1017/CBO9780511812507

Bourdieu, P. (1984). *Distinction. A social Critique of the Judgement of Taste* (R. Nice, Trans.). Cambridge, MA: Harvard University Press. (Original work published 1979)

Boyer, R. (2016). Achieving one-planet living through transitions in social practice: A case study of dancing rabbit ecovillage. Sustainability: Science, Practice, &. *Policy*, *12*(1). doi:10.1080/15487733.2016.11908153

Bragg, A., & Bragg, M. (2005). *Developing new business ideas: A step by step guide to creating new business ideas worth backing*. Harlow, UK: Pearson Education Limited.

Brake, M., & Hook, N. (2008). *Different engines – How science drives fiction and fiction drives science*. New York: Macmillan Science.

Brand, K.-W. (2017): Zur Problematik der Steuerung sozial-ökologischer Transformationsprozesse. In Die sozial-ökologische Transformation der Welt, (pp. 117-154). Frankfurt: Campus.

Brandon, D. P., & Hollingshead, A. B. (2004). Transactive Memory Systems in Organizations: Matching Tasks, Expertise, and People. *Organization Science*, *15*(6), 633–644. doi:10.1287/orsc.1040.0069

Brar, H. K. (2018). *The electrified third "data" rail: how data is powering the Fourth Industrial Revolution.* Retrieved from https://medium.com/predict/the-electrified-third-data-rail-how-data-is-powering-the-fourth-industrial-revolution-dfb60ba64403

Brascamp, J. (2014). *Illustration of the mirror neuron system* Retrieved from Wikipedia wiki: https://commons.wikimedia.org/wiki/File:Illustration-of-the-mirror-neuron-system-by-Jan-Brascamp.jpg

Brecht, S., & Schmucker, H. (2014). Employer Branding im Mittelstand: Strategische Umsetzung bei Wilo. In H. Künzel (Ed.), *Erfolgsfaktor Employer Branding. Mitarbeiter binden und die Gen Y gewinnen* (pp. 201–216). Berlin: Springer-Verlag.

Brenke, K. (2013, May 8). Jugendarbeitslosigkeit sinkt deutlich - regionale Unterschiede verstärken sich. *DIW Wochenbericht*, *19/2013*, 3–13.

Bricusse, L., & Newley, A. (1971). *Pure Imagination. On Willy Wonka & the Chocolate Factory* [LP]. USA: Paramount Records.

Brown, P., Sutikna, T., Morwood, M. J., Soejono, R. P., Jatmiko, Wayhu Saptomo, E., & Awe Due, R. (2004). A new small-bodied hominin from the Late Pleistocene of Flores, Indonesia. *Nature*, *431*(7012), 1055–1061. doi:10.1038/nature02999 PMID:15514638

Buckesfeld, Y. (2012). *Employer Branding: Strategie für die Steigerung der Arbeitgeberattraktivität in KMU*. Hamburg: Diplomica Verlag.

Buderi, R. (2000). *Engines of tomorrow: how the world's best companies are using their research labs to win the future*. New York: Simon & Schuster.

Bukatman, S. (1993). *Terminal Identity: The virtual subject in postmodern science fiction, Durham*. Londres: Duke University Press. doi:10.1215/9780822379287

Busse, T. V., & Mansfield, R. S. (1980). Theories of the creative process: A review and a perspective. *The Journal of Creative Behavior*, *14*(2), 91–103, 132. doi:10.1002/j.2162-6057.1980.tb00232.x

Butcher, L. M., Meaburn, E., Knight, J., Sham, P. C., Schalkwyk, L. C., Craig, I. W., & Plomin, R. (2005). SNPs, microarrays, and pooled DNA: Identification of four loci associated with mild mental impairment in a sample of 6,000 children. *Human Molecular Genetics*, *14*(10), 1315–1325. doi:10.1093/hmg/ddi142 PMID:15800012

Byrne, R. (2006). *The Secret*. New York: Atria Books.

Cagle, M. (1985). A general abstract–concrete model of creative thinking. *The Journal of Creative Behavior*, *19*(2), 104–109. doi:10.1002/j.2162-6057.1985.tb00643.x

Capece, G., & Costa, R. (2009). Measuring knowledge creation in virtual teams through the social network analysis. *Knowledge Management Research and Practice*, *7*(4), 329–338. doi:10.1057/kmrp.2009.25

Carl, M., & Gondlach, K. (2018). *Die Zukunft des deutschen Mittelstandes: Innovationen durch Digitalisierung*. Leipzig: 2b AHEAD.

Carruth, A. (2014). The digital cloud and the micropolitics of energy. *Public Culture*, *26*(2), 339–364. doi:10.1215/08992363-2392093

Carson, S. (2013). Creativity and Psychopathology: Shared Neurocognitive Vulnerabilities. In O. Vartanian, A. S. Bristol, & J. C. Kaufman (Eds.), *Neuroscience of Creativity*. Cambridge, MA: MIT Press. doi:10.7551/mitpress/9780262019583.003.0009

Castoriadis, C. (1990). *Gesellschaft als imaginäre Institution. Entwurf einer politischen Philosophie*. Frankfurt am Main, Germany: Suhrkamp. (Original work published 1984)

Central Intelligence Agency. (2019). Taiwan. *The World Fact Book*. Retrieved May 03, 2019 from https://www.cia.gov/library/publications/resources/the-world-factbook/geos/tw.html

Central News Agency. (2015, July 14). Taiwan the 17th richest country in world: Global Finance. *Taiwan News Online*. Retrieved April 01, 2019 from http://www.taiwannews.com.tw/etn/news_content.php?id=2770386&lang=eng_news&cate_rss=news_Economics

Changeux, J.-P., & Connes, A. (1995). *Conversations on Mind, Matter, and Mathematics*. Princeton, NJ: Princeton University Press.

Chaurasia, R. (2018). Ransomware: The Cyber Extortionist. In Z. Fields (Ed.), *Handbook of Research on Information and Cyber Security in the Fourth Industrial Revolution*. Hershey, PA: IGI Global. doi:10.4018/978-1-5225-4763-1.ch003

Chen, C., & Huang, F. (2015, July 22). Average wages in first 5 months of 2015 up 3.54%. *Focus Taiwan*. Retrieved April 05, 2019 from http://focustaiwan.tw/news/aeco/201507220023.aspx

Christensen, C. M., & Eyring, H. J. (2011). *The Innovative University: Changing the DNA of Higher Education*. San Francisco, CA: Jossey-Bass.

Christensen, C. M., Horn, M. B., & Johnson, C. W. (2011). *Disrupting Class: How disruptive innovation will change the way the world learns*. New York: McGraw-Hill Education.

Christoff, K., Irving, Z. C., Fox, K. C., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature Reviews. Neuroscience*, *17*(11), 718–731. doi:10.1038/nrn.2016.113 PMID:27654862

Claridge, G. (Ed.). (1997). *Schizotypy: Implications for illness and health*. New York: Oxford University Press. doi:10.1093/med:psych/9780198523536.001.0001

Clegg, M. (2012). The Evolution of the Human Vocal Tract. In N. Bannan (Ed.), *Music, Language and Human Evolution*. Oxford, UK: Oxford University Press. doi:10.1093/acprof:osobl/9780199227341.003.0003

Colombo, A. W., Stamatis, K., Okyay, K., Shi, Y., & Shen, Y. (2017). Industrial cyberphysical systems: A backbone of the Fourth Industrial Revolution. *IEEE IEM*, *11*(1), 1–10.

Coolidge, F. L., & Wynn, T. (2018). *The Rise of Homo sapiens: The Evolution of Modern Thinking* (2nd ed.). Oxford University Press.

Cornelis, A., & de Kluyver, K. (2012). *Global strategy*. Oxford, UK: Lardbucket.

Cornelius, C., & Boos, M. (2003). Enhancing mutual understanding in synchronous computer-mediated communication by training: Trade-offs in judgmental tasks. *Communication Research*, *30*(2), 147–177. doi:10.1177/0093650202250874

Craft, A. (2005). *Creativity in Schools: Tensions and Dilemmas*. Routledge. doi:10.4324/9780203357965

Cramton, C. D. (2001). The mutual knowledge problem and its consequences for dispersed collaboration. *Organization Science*, *12*(3), 346–371. doi:10.1287/orsc.12.3.346.10098

Cropley, A. J. (2012). Creativity and education: An Australian perspective. *The International Journal of Creativity & Problem Solving*, *22*(1), 9–25.

Cropley, D. H. (2008). Fostering and measuring creativity and innovation: Individuals, organisations and products. *Mendeley Issue*, *1942*, 267–278.

Cropley, D. H., & Cropley, A. J. (2016). Promoting creativity through assessment: A formative CAA tool for teachers. *Educational Technology Magazine*, *56*(6), 17–24.

Cross, N. (Ed.). (1972). Design Participation. In *Proceedings of the Design Research Society's Conference*. London: Academy Editions.

Currie, G., & Ravenscroft, I. (2002). *Recreative Minds: Imagination in Philosophy and Psychology*. Oxford, UK: Clarendon Press. doi:10.1093/acprof:oso/9780198238089.001.0001

Curşeu, P. L., & Rus, D. (2005). The cognitive complexity of groups A critical look at team cognition research. *Cogniţie Creier Comportament*, *9*(4), 681–710.

Curtin, M. (2018). *The top 10 skills that will land you high-paying jobs by 2020.* Retrievable from https://www.inc.com/melanie-curtin/the-10-top-skills-that-will-land-you-high-payingjobs-by-2020-according-to-world-economic-forum.html

Curtis, D. (2004). Re-analysis of collaborative study on the genetics of alcoholism pedigrees suggests the presence of loci influencing novelty-seeking near D12S391 and D17S1299. *Psychiatric Genetics*, *14*(3), 151–155. doi:10.1097/00041444-200409000-00006 PMID:15318029

D'Alisa, G. (Ed.). (2015). *Degrowth: a vocabulary for a new era*. New York: Routledge.

Daft, R. L., & Lengel, R. H. (1986). Organizational information requirements, media richness and structural design. *Management Science*, *32*(5), 554–571. doi:10.1287/mnsc.32.5.554

Dagevos, H., & Voordouw, J. (2013). Sustainability and meat consumption: Is reduction realistic? *Sustainability: Science, Practice, & Policy, 9*(2).

Dahlmanns, A. (2014). *Generation Y und Personalmanagement*. Munich: Rainer Hampp Verlag.

Dalkir, K. (2005). *Knowledge management in theory and practice*. Burlington, MA: Elsevier Butterworth-Heinemann.

Dampérat, M., Jeannot, F., Jongmans, E., & Jolibert, A. (2016). Team creativity: Creative self-efficacy, creative collective efficacy and their determinants. *Recherche et Applications en Marketing*, *31*(3), 6–25. doi:10.1177/2051570716650164

Darwin, C. (1859). *On the origin of species by means of natural selection, or, the preservation of favoured races in the struggle for life*. London: J. Murray.

Davies, A., Fidler, D., & Gorbis, M. (2011). *Future work skills 2020*. Retrieved from http://www.iftf.org/uploads/media/SR-1382A_UPRI_future_work_skills_sm.pdf

Davies, G., Tenesa, A., Payton, A., Yang, J., Harris, S. E., Liewald, D., ... Deary, I. J. (2011). Genome-wide association studies establish that human intelligence is highly heritable and polygenic. *Molecular Psychiatry*, *16*(10), 996–1005. doi:10.1038/mp.2011.85 PMID:21826061

Davis, E. (2015). *TechGnosis: Myth, Magic, and Mysticism in the Age of Information*. Berkeley: North Atlantic Books.

de Beaune, S. A. (2004). The invention of technology: Prehistory and cognition. *Current Anthropology*, *45*(2), 139–162. doi:10.1086/381045

De Brabandere, L., & Iny, A. (2013). *A new paradigm for business creativity: Thinking in new boxes*. New York, NY: Random House Publishing Group.

De Smet, A., Lackey, G., & Weiss, L. M. (2017). *Untangling your organization's decision-making*. Retrieved from https://www.mckinsey.com/business-functions/organization/our-insights/untangling-your-organizations-decision-making

De Villiers, J. M., Duke, L. L., & Jansen van Nieuwenhuizen, P. J. (2017). *The Fourth Industrial Revolution: Highlighting the South African Skills Crisis*. Retrieved March 5, 2019 from https://www.skills-universe.com/2017/10/28/the-fourth-industrial-revolution-highlighting-the-south-african-skills-crisis/

De Witt, D. K. (2003). *Astrofuturism: science, race and visions of utopia in space*. University of Pennsylvania Press.

Deacon, T. W. (1997). *The Symbolic Species*. New York: W. W. Norton.

Deary, I. J., Johnson, W., & Houlihan, L. M. (2009). Genetic foundations of human intelligence. *Human Genetics*, *126*(1), 215–232. doi:10.100700439-009-0655-4 PMID:19294424

Deary, I. J., Penke, L., & Johnson, W. (2010). The neuroscience of human intelligence differences. *Nature Reviews. Neuroscience*, *11*(3), 201–211. doi:10.1038/nrn2793 PMID:20145623

Dennett, D. (1976). Conditions of personhood. In A. Rorty (Ed.), *The identities of persons*. Berkeley, CA: University of California Press.

Desouza, K. C., Dombrowski, C., Awazu, Y., Baloh, P., Papagari, S., Jha, S., & Kim, J. Y. (2009). Crafting organizational innovation processes. Innovation: Management. *Policy & Practice*, *11*(1), 6–33. doi:10.5172/impp.453.11.1.6

Dessler, G. (2015). *Human Resource Management*. Harlow: Pearson Education.

DiCicco-Bloom, B., & Crabtree, B. F. (2006). The Qualitative Research Interview. *Medical Education*, *40*(4), 314–321. doi:10.1111/j.1365-2929.2006.02418.x PMID:16573666

Dick, D. M., Aliev, F., Bierut, L. J., Goate, A., Rice, J., Hinrichs, A., ... Hesselbrock, V. (2006). Linkage analysis of IQ in the collaborative study on the genetics of alcoholism (COGA) sample. *Behavior Genetics*, *36*(1), 77–86. doi:10.100710519-005-9009-8 PMID:16341907

Disch, T. (2000). *The dreams our stuff is made of: how science fiction conquered the world*. New York, Londres, Toronto: Free Press.

Donald, M. (1991). *Origins of the modern mind: Three stages in the evolution of culture and cognition*. Cambridge, MA: Harvard University Press.

Dooren, C. v., & Bosschaert, T. (2013). Developing and disseminating a foodprint tool to raise awareness about healthy and environmentally conscious food choices. Sustainability: Science, Practice, &. *Policy*, *9*(2), 70–82. doi:10.1080/15487733.2013.11908116

Döring, N., & Bortz, J. (2016). *Forschungsmethoden und Evaluation*. Heidelberg, Germany: Springer.

Dorsch, F. (2016). Knowledge by Imagination — How Imaginative Experience Can Ground Factual Knowledge. *Teorema: Revista Internacional De Filosofía*, *35*(3), 87-116. Retrieved from http://www.jstor.org/stable/44077413

Dosi, G. (1982). Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinant and Direction of Technological Change. *Research Policy*, *11*(3), 147–162. doi:10.1016/0048-7333(82)90016-6

Douglas, M. (1995). *Purity and Danger: an analysis of the concepts of pollution and taboo*. London: Routledge. (Original work published 1966)

Dregni, E. (2006). Follies of science – 20th century visions of our fantastic future. Denver, CO: Speck Press.

Drucker, P. F. (1993). *Post-Capitalist Society*. Oxford, UK: Elsevier Butterworth Heinemann.

Duden. (2018). *Nachhaltigkeit*. Retrieved from https://www.duden.de/rechtschreibung/Nachhaltigkeit

Dunbar, R. (2004). *The Human Story*. London: Faber and Faber.

Durier, V., Graham, P., & Collett, T. S. (2003). Snapshot Memories and Landmark Guidance in Wood Ants. *Current Biology*, *13*(18), 1614–1618. doi:10.1016/j.cub.2003.08.024 PMID:13678592

Durrant-Whyte, H., Geraghty, R., Pujol, F., & Sellschop, R. (2015). *How digital innovation can improve mining productivity*. Retrieved from http://www.mckinsey.com/industries/metalsand-mining/our-insights/how-digital-innovation-can-improve-mining-productivity

Ebstein, R. P., Novick, O., Umansky, R., Priel, B., Osher, Y., Blaine, D., ... Belmaker, R. H. (1996). Dopamine D4 receptor (DRD4) exon III polymorphism associated with the human personality trait of novelty seeking. *Nature Genetics*, *12*(1), 78–80. doi:10.1038/ng0196-78 PMID:8528256

Edelman, G. (1987). *Neural Darwinism*. New York: Basic Books.

Edelman, G. (1989). *The remembered present: A biological theory of consciousness*. New York: Basic Books.

Edelman, G. (1999). Building a picture of the brain. *Annals of the New York Academy of Sciences*, *882*(1), 70. PMID:10415887

Edelman, G., & Tononi, G. (2000). *A universe of consciousness: How matter becomes imagination*. New York: Basic Books.

Edgar, I. R. (2004). Imagework in ethnographic research. In Working Images. Visual Research and Representation in Ethnography (pp. 90-106). London, UK: Routledge.

Edmondson, A. (1999). Psychological Safety and Learning Behavior in Work Team. *Administrative Science Quarterly*, *44*(2), 350–383. doi:10.2307/2666999

Edmondson, A. (2002). The local and variegated nature of learning in organizations: A group-level perspective. *Organization Science*, *13*(2), 128–146. doi:10.1287/orsc.13.2.128.530

Edublox Online Tutor. (2019). *Cognitive skills: what are they and why they are important?* Retrieved March 5, 2019 from https://www.edubloxtutor.com/tag/cognitive-development/

Eiduson, B. (1960). The Scientist's Image of himself. *Science*, *132*(3426), 552–554. doi:10.1126cience.132.3426.552-a PMID:17798831

Eiduson, B. (1962). *Scientists. Their Psychological World*. New York, NY: Basic Books.

Eiduson, B. (1966 a). Productivity Rate in Research Scientists. *American Scientist*, *54*, 57–63. PMID:5907922

Eiduson, B. (1966 b). Scientists as Advisors and Consultants in Washington. *Bulletin of the Atomic Scientists*, *22*(8), 26–31. doi:10.1080/00963402.1966.11454975

Eiduson, B., & Beckman, L. (1973). *Science as a Career Choice*. New York, NY: Russell Sage.

Eindhoven, J. E., & Vinacke, W. E. (1952). Creative processes in painting. *The Journal of General Psychology*, *47*(2), 165–179. doi:10.1080/00221309.1952.9710660

Elias, N. (1998). The Kitsch Style and the Age of Kitsch (E. Jephcott, Trans.). In J. Goudsblom & S. Mennell (Eds.), The Norbert Elias Reader: A Biographical Selection, (pp. 26-31). Oxford, UK: Blackwell.

Entzian, A. (2015). *Denn sie tun nicht, was sie wissen. Eine Studie zu ökologischem Bewußtsein und Handeln*. München: oekom.

Epstein, R., Schmidt, S. M., & Warfel, R. (2008). Measuring and training creativity competencies: Validations of a new test. *Creativity Research Journal*, *20*(1), 7–12. doi:10.1080/10400410701839876

Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: A magnetic stimulation study. *Journal of Neurophysiology*, *73*(6), 2608–2611. doi:10.1152/jn.1995.73.6.2608 PMID:7666169

Fang, Y., Kwok, R. C.-W., & Schroeder, A. (2014). Knowledge processes in virtual teams: Consolidating the evidence. *Behaviour & Information Technology*, *33*(5), 486–501. doi:10.1080/0144929X.2012.719033

Faw, B. (1997). Outlining a Brain Model of Mental Imaging Abilities. *Neuroscience and Biobehavioral Reviews*, *21*(3), 283–288. doi:10.1016/S0149-7634(96)00026-7 PMID:9168264

Faw, B. (2009). Conflicting Intuitions May be Based on Differing Abilities: Evidence from Mental Imaging Research. *Journal of Consciousness Studies*, *16*(4), 45–68.

Featherstone, M. (2007). *Consumer Culture and Postmodernism* (2nd ed.). London: Sage.

Feist, G. (1998). A Meta-Analysis of Personality in Scientific and Artistic Creativity. *Personality and Social Psychology Review*, *2*(4), 290–309. doi:10.120715327957pspr0204_5 PMID:15647135

Fellmann, F. (1991). *Symbolischer Pragmatismus. Hermeneutik nach Dilthey*. Hamburg, Germany: Rowohlt.

Fields, Z., & Atiku, S. O. (2015). Testing and Operationalizing a Model to Measure Creativity at Tertiary Educational Level. *International Journal of Educational Sciences*, *9*(3), 283–296. doi:10.1080/09751122.2015.11890318

Fields, Z., & Sulaiman, O. A. (2017). Collective Green Creativity and Eco-Innovation as Key Drivers of Sustainable Business Solutions in Organizations. In Z. Fields (Ed.), *Collective creativity for responsible and sustainable business practice* (pp. 1–25). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-1823-5.ch001

Filimon, F., Nelson, J. D., Hagler, D. J., & Sereno, M. I. (2007). Human cortical representations for reaching mirror neurons for execution, observation and imagery. *NeuroImage*, *37*(4), 1315–1328. doi:10.1016/j.neuroimage.2007.06.008 PMID:17689268

Finke, R. A. (1990). *Creative imagery: Discoveries and inventions in visualization*. Hillsdale, NJ: Erlbaum.

Finke, R. A., Pinker, S., & Farah, M. J. (1989). Reinterpreting visual patterns in mental imagery. *Cognitive Science*, *13*(1), 51–78. doi:10.120715516709cog1301_2

Fiol, C. M., & O'Connor, E. J. (2005). Identification in Face-to-Face, Hybrid, and Pure Virtual Teams: Untangling the Contradictions. *Organization Science*, *16*(1), 19–32. doi:10.1287/orsc.1040.0101

Fischer, R. A. (2018). Towards Sustainable Global Value Chains: The Role of The Group of Seven. In A-M. Schneider & S. Jastram (Eds.), Sustainable fashion. Governance and new management approaches, (pp. 25-39). Cham: Springer.

Ford, M. (2015). *The rise of the robots: technology and the threat of mass unemployment*. London: Oneworld Publications.

Foucault, M. (1980). *Power/Knowledge*. Harlow, UK: Prentice Hall.

Freeland, C. A. (1997). Art and moral knowledge. *Philosophical Topics*, *25*(1), 11–36. doi:10.5840/philtopics19972518

Gabler Wirtschaftslexikon. (2018). *Nachhaltigkeit*. Retrieved from https://wirtschaftslexikon.gabler.de/definition/nachhaltigkeit-41203

Gabora, L., & Kaufman, S. B. (2010). Evolutionary Approaches to Creativity. In J. C. Kaufman & R. J. Sternberg (Eds.), *The Cambridge Handbook of Creativity*. New York, NY: Cambridge University Press. doi:10.1017/CBO9780511763205.018

Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain*, *119*(2), 593–609. doi:10.1093/brain/119.2.593 PMID:8800951

Galton, F. (1880a). Statistics of Mental Imagery. *Mind*, *5*(19), 301–318. doi:10.1093/mind/os-V.19.301

Galton, F. (1880b). Visualized Numerals. *Nature*, *21*(533), 252–256. doi:10.1038/021252a0

Galton, F. (1880c). Mental Imagery. *Fortnightly Review*, *28*, 312–324.

Galton, F. (1883). *Inquiries into Human Faculty and its Development*. London: Macmillan. doi:10.1037/14178-000

Gauntlett, D. (2007). *Creative Explorations. New approaches to identities and audiences*. London, UK: Routledge. doi:10.4324/9780203961407

Gaut, B. (2003). Creativity and Imagination. In B. Gaut & P. Livingston (Eds.), *The Creation of Art: New Essays in Philosophical Aesthetics*. Cambridge University Press.

Gerardin, E., Siriqu, A., Lehéricy, S., Poline, J. B., Gaymard, B., Marsault, C., & ... . (2000). Par- tially overlapping neural networks for real and imagined hand movements. *Cerebral Cortex*, *10*(11), 1093–1104. doi:10.1093/cercor/10.11.1093 PMID:11053230

Ghiselin, B. (1956). The creative process and its relation to the identification of creative talent. In C. W. Taylor (Ed.), *The 1955 University of Utah research conference on the identification of creative scientific talent*. Salt Lake City, UT: University of Utah Press.

Ghiselin, B. (1963). Automatism, intention, and autonomy in the novelist's production. *Daedalus*, *92*, 297–311.

Ghiselin, B. (Ed.). (1985). *The creative process: A symposium*. Berkeley, CA: University of California Press.

Godemann, J., & Bartelmeß, T. (2018). Gesellschaftliche Verständigung über ein Totalphänomen. Zum Verständnis nachhaltigkeitsbezogener Ernährungskommunikation. In T. Phyel (Ed.), Zwischen Ohnmacht und Zuversicht. Vom Umgang mit Komplexität in der Nachhaltigkeitskommunikation (pp. 187-206). München: oekom.

Göke, N. (2018). *The Future of Learning*. Retrieved December 15, 2018 from https://medium.com/s/story/what-is-the-future-of-learning-3ff625d1dc86

Golchert, J., Smallwood, J., Jefferies, E., Seli, P., Huntenburg, J. M., Liem, F., ... Margulies, D. S. (2016). Individual variation in intentionality in the mind-wandering state is reflected in the integration of the default-mode, fronto-parietal, and limbic networks. *NeuroImage*, *146*, 226–235. doi:10.1016/j.neuroimage.2016.11.025 PMID:27864082

Goodall, J. (1996). *The Chimpanzees of Gombe*. Cambridge, MA: Harvard University Press.

Goswami, A. (1996). Creativity and the quantum: A unified theory of creativity. *Creativity Research Journal*, *9*(1), 47–61. doi:10.120715326934crj0901_5

Gould, J. L. (1990). Honey Bee Cognition. *Cognition*, *37*(1-2), 83–103. doi:10.1016/0010-0277(90)90019-G PMID:2269009

Gould, S. J., & Vrba, E. S. (1982). Exaptation: A missing term in the science of form. *Paleobiology*, *8*(1), 4–15. doi:10.1017/S0094837300004310

Graham, L. (2013). *Bouncing back: rewiring your brain for maximum resilience and well-being*. New World Library.

Gray, A. (2015). *The 10 skills you need to thrive in the Fourth Industrial Revolution*. Retrievable from https://www.weforum.org/agenda/2016/01/the-10-skills-you-need-to-thrive-in-thefourth-industrial-revolution

Gray, A. (2016). *The 10 skills you need to thrive in the Fourth Industrial Revolution*. The World Economic Forum. Retrieved February 10, 2019 from https://www.weforum.org/agenda/2016/01/the-10-skills-you-need-to-thrive-in-the-fourth-industrial-revolution/

Greogry, D. (2016). Imagination and mental imagery. In A. Kind (Ed.), *The Routledge Handbook of Philosophy of Imagination*. New York: Routledge.

Griffith, T. L., & Neale, M. A. (2001). Information processing in traditional, hybrid and virtual teams: From nascent knowledge to transactive memory. *Research in Organizational Behavior*, *23*, 379–421. doi:10.1016/S0191-3085(01)23009-3

Gross, P. (1995). *Die Multioptionsgesellschaft*. Frankfurt am Main: Suhrkamp.

Guilford, J. P. (1950). Creativity. *The American Psychologist*, *5*(9), 444–454. doi:10.1037/h0063487 PMID:14771441

Guilford, J. P. (1967). *The nature of human intelligence*. New York: McGraw-Hill.

Gunes, V., Peter, S., Givargis, T., & Vahid, F. (2014). A survey on concepts, applications, and challenges in Cyber-Physical Systems. *Transactions on Internet and Information Systems (Seoul)*, *8*(12), 4242–4268.

Gusnard, D. A., Akbudak, E., Shulman, G. L., & Raichle, M. E. (2001). Medial prefrontal cortex and self-referential mental activity: Relation to a default mode of brain function. *Proceedings of the National Academy of Sciences of the United States of America*, *98*(7), 4259–4264. doi:10.1073/pnas.071043098 PMID:11259662

Gustein, A. J., & Sviokla, J. (2018). *7 Skills that aren't to be automated*. Retrievable from https://hbr.org/2018/07/7-skills-that-arent-about-to-be-automated

Haas, M. R. (2006). Acquiring and applying knowledge in transnational teams: The roles of cosmopolitans and locals. *Organization Science*, *17*(3), 367–384. doi:10.1287/orsc.1060.0187

Hadamard, J. (1945). *An essay on the psychology of invention in the mathematical field*. Princeton, NJ: Princeton University Press.

Halverson, C. A. (2002). Activity Theory and Distributed Cognition: Or What Does CSCW Need to DO with Theories? *Computer Supported Cooperative Work: The Journal of Collaborative Computing*, *11*(1/2), 243–267. doi:10.1023/A:1015298005381

Hampton, J. A. (1987). Inheritance of attributes in natural concept conjunctions. *Memory & Cognition*, *15*(1), 55–71. doi:10.3758/BF03197712 PMID:3821491

Hansen, M. T., Nohria, H., & Tierney, T. (1999). What's your strategy for managing knowledge. *Harvard Business Review*, *77*(2), 106–116. PMID:10387767

Harley, B., & Nolan, C. T. (2014). HRM in Small and Medium Sized Enterprises. In B. Harley & K. Monks (Eds.), *Strategic HRM: Research and Practice in Ireland* (pp. 153–169). Dublin: Orpen Press.

Hartford, T. (2019). *A powerful way to unleash your natural creativity*. Retrieved from https://www.ted.com/talks/tim_harford_a_powerful_way_to_unleash_your_natural_creativity/transcript?language=en

Hasnas, J. (2009). Two Theories of Environmental Regulation. *Social Philosophy & Policy*, *26*(2), 95–129. doi:10.1017/S0265052509090189

Hawkes, K., O'Connell, J. F., & Blurton-Jones, N. G. (1997). Hadza women's time allocation, offspring provisioning, and the evolution of long post-menopausal life-spans. *Current Anthropology*, *38*(4), 551–578. doi:10.1086/204646

Hayward, P. (2002). A comparison of face-to-face and virtual software development teams. *Team Performance Management*, *8*(1/2), 39–48. doi:10.1108/13527590210425077

Hebb, D. (1949). *The Organization of Behaviour: A Neuropsychological Theory*. New York, NY: John Wiley & Sons.

Hebdige, D. (1979). *Subculture. The Meaning of Style*. London: Methuen.

Heersmink, R., & Knight, S. (2018). Distributed learning: Educating and assessing extended cognitive systems. *Philosophical Psychology*, *31*(6), 969–990. doi:10.1080/09515089.2018.1469122

Heinrichs, H. (2011). Participation: Empowerment for Sustainable Consumption. In J. Godeman & G. Michelsen (Eds.), *Sustainability Communication. Interdisciplinary Perspectives and Theoretical Foundations* (pp. 187–198). Heidelberg, Germany: Springer.

Henry, J. (Ed.). (1991). *Creative management*. London: SAGE Publications Ltd.

Hertel, G., Geister, S., & Konradt, U. (2005). Managing virtual teams: A review of current empirical research. *Human Resource Management Review*, *15*(1), 69–95. doi:10.1016/j.hrmr.2005.01.002

Hess, D. (2010). Sustainable consumption and the problem of resilience. Sustainability: Science. *Practice and Policy*, *6*(2), 26–37.

Heylighen, F., Heath, M. & Van, F. (2004). The Emergence of Distributed Cognition: a conceptual framework. *Proceedings of Collective Intentionality IV.*

Hitzler, R., & Niederbacher, A. (2010). Leben in Szenen. Formen juveniler Vergemeinschaftung heute (3rd ed.). Wiesbaden: VS. doi:10.1007/978-3-531-92532-5

Hitzler, R., & Honer, A. (1994). Bastelexistenz. Über subjektive Konsequenzen der Individualisierung. In U. Beck & E. Beck-Gernsheim (Eds.), *Riskante Freiheiten. Individualisierung in modernen Gesellschaften* (pp. 307–315). Frankfurt am Main: Suhrkamp.

Hobson, P., Chidambi, G., & Meyer, J. (2006). Foundations for self- awareness: An exploration through autism. *Monographs of the Society for Research in Child Development*, *71*, vii-166. PMID:17177915

Hoen, A. (2017a). *Creative intelligence in Organizations – Insights for executives.* Retrieved from: https://veld.fm/creative-intelligence-in-organisations-e9eefb96068f

Hoen, A. (2017b). *How to use a heuristic to unlock creative intelligence and become more innovative*. Retrieved from: https://veld.fm/how-to-use-a-heuristic-to-unlock-creative-intelligence-and-become-more-innovative-fe069b0af28b

Holdt Christensen, P., & Pedersen, T. (2018). The dual influences of proximity on knowledge sharing. *Journal of Knowledge Management*, *22*(8), 1782–1802. doi:10.1108/JKM-03-2018-0211

Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed cognition: Toward a new foundation for human-computer interaction research. *ACM Transactions on Computer-Human Interaction*, *7*(2), 174–196. doi:10.1145/353485.353487

Hong, C. (2017). Design of human-computer interaction interface considering user friendliness. *International Journal of Reasoning-Based Intelligent Systems*, *9*(3), 162–169. doi:10.1504/IJRIS.2017.090044

Honneth, A. (1992). *Kampf um Anerkennung: zur moralischen Grammatik sozialer Konflikte*. Frankfurt am Main: Suhrkamp.

Hopf, C. (2004). Qualitative Interviews - ein Überblick. In U. Flick, E. V. Kardoff, & I. Steinke (Eds.), Qualitative Forschung. Ein Handbuch (pp. 349-360). Reinbeck bei Hamburg: Rowohlt.

Howard-Jones, P. A., Blakemore, S. J., Samuel, E. A., Summers, I. R., & Claxton, G. (2005). Semantic divergence and creative story generation: An fMRI investigation. *Brain Research. Cognitive Brain Research*, *25*(1), 240–250. doi:10.1016/j.cogbrainres.2005.05.013 PMID:15993573

Hu, E. (2015, December 8). Taiwan's 'Strawberry Generation' Reaches Out To The Young And Trendy. *NPR Parallels*. Retrieved April 15, 2019 from http://www.npr.org/sections/parallels/2015/12/08/458131681/taiwans-strawberry-generation-reaches-out-to-the-young-and-trendy

Huang, T. (2018, April 30). Taiwan has the 6th longest working hours in the world: survey. *Taiwan News.* Retrieved May 2, 2019 from https://www.taiwannews.com.tw/en/news/3418188

Hughes, R. L., Ginnette, R. C., & Curphy, G. J. (2015). *Leadership: Enhancing lessons of experience* (8th ed.). Singapore: McGraw-Hill Education.

Huss, E. (2012). What we see and what we say: Combining visual an verbal information within socialwork research. *British Journal of Social Work*, *42*(8), 1440–1459. doi:10.1093/bjsw/bcr155

Hutchins, E. (1995). *Cognition in the Wild*. Cambridge, MA: MIT Press.

Hutchins, E. (2000). The Cognitive Consequences of Patterns of Information Flow. *Intellectica*, *1*(30), 53–74. doi:10.3406/intel.2000.1593

Hutchins, E. (2010). Cognitive ecology. *Topics in Cognitive Science*, *2*(4), 705–715. doi:10.1111/j.1756-8765.2010.01089.x PMID:25164051

Hutchins, E. (2011). Enculturating the Supersized Mind. *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, *152*(3), 437–446. doi:10.100711098-010-9599-8

Hutchins, E. (2014). The cultural ecosystem of human cognition. *Philosophical Psychology*, *27*(1), 34–49. doi:10.1080/09515089.2013.830548

IBM. (n.d.). *The quest for AI creativity*. Retrieved from: https://www.ibm.com/watson/advantage-reports/future-of-artificial-intelligence/ai-creativity.html#section3

Imran, M., Ariff, M., Sharma, R., & Arshad, N. I. (2015). Exploring the Role of Transactive Memory Systems in Virtual Teams: Review and synthesis of literature. *International Symposium on Mathematical Sciences and Computing Research (iSMSC)* 10.1109/ISMSC.2015.7594070

IPCC (Intergovernmental Panel of Climate Change). (2018). *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Geneva, Switzerland: World Meteorological Organization.

Ishwarappa, K., & Anuradha, J. (2015). A brief introduction on big data 5Vs characteristics and Hadoop technology. *Procedia Computer Science*, *48*, 319–324. doi:10.1016/j.procs.2015.04.188

Jackson, P., Skirrow, P., & Hare, D. J. (2012). Asperger through the looking glass: An exploratory study of self-understanding in people with Asperger's syndrome. *Journal of Autism and Developmental Disorders*, *42*(5), 697–706. doi:10.100710803-011-1296-8 PMID:21647793

Jackson, T. (2009). *Prosperity without growth: Economics for a finite planet*. London: Earthscan. doi:10.4324/9781849774338

Jaeger-Erben, M., Rückert-John, J., & Schäfer, M. (2015). Sustainable consumption through social innovation: A typology of innovations for sustainable consumption practices.'. *Journal of Cleaner Production*, *108*, 784–798. doi:10.1016/j.jclepro.2015.07.042

Jamison, K. (1989). Mood disorders and patterns of creativity in British writers and artists. *Psychiatry*, *52*(2), 125–134. doi:10.1080/00332747.1989.11024436 PMID:2734415

Jamison, K. R. (1993). *Touched with fire*. New York: Free Press.

Janus, S. S. (2016). *Becoming a knowledge sharing-organization: a handbook for scaling up solutions through knowledge capturing and sharing*. Washington, DC: International Bank for Reconstruction and Development / The World Bank. doi:10.1596/978-1-4648-0943-9

Jarvenpaa, S. L., Knoll, K., & Leidner, D. E. (1998). Is anybody out there? The implications of trust in global virtual teams. *Journal of Management Information Systems*, *14*(4), 29–64. doi:10.1080/07421222.1998.11518185

Jezard, A. (2018). *The 3 key skill sets for the workers of 2030.* World Economic Forum. Retrieved February 10, 2019 from https://www.weforum.org/agenda/2018/06/the-3-skill-sets-workers-need-to-develop-between-now-and-2030/

Johansson, R. (2003). *Case study methodology*. Retrieved from http://www.psyking.net/htmlobj-3839/case_study_methodology-rolf_johansson_ver_2.pdf/

John, E. (2013). Art and knowledge. In The Routledge Companion to Aesthetics. New York, NY: Routledge.

John, R. & Jaeger-Erben M. & Rückert-John, J. (2016). Elusive Practices: Considerations on limits and possibilities of environmental policy for sustainable consumption. *Journal of Environmental Policy and Governance*, 129-140. doi:10.1002/eet.1706

Johnson, W. (2017). *Pros & Cons of Global Companies*. Retrieved from https://bizfluent.com/info-7756133-pros-cons-global-companies.html

Johnson, B. D. (2011). *Science fiction for prototyping: Designing the future with science fiction*. Morgan & Claypool Publishers.

Kaldero, N. (2019). *How to lead a data driven organisation.* Disruption Insights. Retrieved February 10, 2019 from https://disruptionhub.com/how-to-lead-a-data-driven-organisation-nir-kaldero-6327/

Kant, I. (2006). *Anthropology from a Pragmatic Point of View* (R. Louden, Trans.). Cambridge, UK: Cambridge University Press.

Kaufman, A. B., Kornilov, S. A., Bristol, A. S., Tan, M., & Grigorenko, E. L. (2010). The neurobiological foundation of Creative Cognition. In J. C. Kaufman & R. J. Sternberg (Eds.), *The Cambridge Handbook of Creativity*. New York, NY: Cambridge University Press. doi:10.1017/CBO9780511763205.014

Kaufman, J. C., & Beghetto, R. A. (2009). Beyond Big and Little: The Four C Model of Creativity. *Review of General Psychology*, *13*(1), 1–12. doi:10.1037/a0013688

Kauppila, O., Rajala, R., & Jyrämä, A. (2011). Knowledge sharing through virtual teams across borders and boundaries. *Management Learning*, *42*(4), 395–418. doi:10.1177/1350507610389685

Kautt, Y. (2008). *Image. Zur Genealogie eines Kommunikationscodes der Massenmedien*. Bielefeld: Transcript.

Kennedy, E. H., Beckley, T. M., McFarlane, B. L., & Nadeau, S. (2009). Why don't we >walk the talk<: Understanding the environmental values/behavior gap in Canada. *Human Ecology Review*, *16*, 151–160.

Kessel, M., Kratzer, J., & Schultz, C. (2012). Psychological Safety, Knowledge Sharing, and Creative Performance in Healthcare Teams. *Creativity and Innovation Management*, *21*(2), 147–157. doi:10.1111/j.1467-8691.2012.00635.x

Kezsbom, D. (2000). Creating teamwork in virtual teams. *Cost Engeneering*, *42*, 33–36.

Kind, A. (2018). How imagination gives rise to knowledge. In M. Macpherson & F. Dorsch (Eds.), *Perceptual Imagination and Perceptual Memory*. Oxford, UK: Oxford University Press.

Kirby, J. (2017). Fleshing out an ecological habitus: Field and capitals of radical environmental movements. *Nature and Culture*, *12*(2), 89–114. doi:10.3167/nc.2017.120201

Kirk, W. B., & Kasser, T. (2005). Are psychological and ecological well-being compatible? the role of values, mindfulness, and lifestyle. *Social Indicators Research*, *74*(2), 349–368. doi:10.100711205-004-8207-8

Klein, G. (1999). *Sources of power: how people make decisions*. Boston, MA: Massachusetts Institute of Technology.

Klitmøller, A., & Lauring, J. (2013). When global virtual teams share knowledge: Media richness, cultural difference and language commonality. *Journal of World Business*, *48*(3), 398–406. doi:10.1016/j.jwb.2012.07.023

Klöppel, M. (2016, November 29). Statistisches Jahrbuch 2016 liegt vor – Einkommen und Geburtenrate im Blick. *Leipziger Volkszeitung Online.* Retrieved April 03, 2019 from http://www.lvz.de/Mitteldeutschland/News/Statistisches-Jahrbuch-2016-liegt-vor-Einkommen-und-Geburtenrate-im-Blick

Klotz-Engmann, G. (2014). *Internationale Normung für Prozess-Sensoren*. Paper presented at the Summit for Microsystem technology, Freiburg, Germany.

Knapp, R. J. (2017). The effects of psychological safety, team efficacy, and transactive memory system development on team learning behavior in virtual work teams. *Dissertation Abstracts International. A, The Humanities and Social Sciences*.

Knickrehm, M. (2018). *How will AI change work: Here are five schools of thought*. Retrievable from https://hbr.org/2018/01/how-will-ai-change-work-here-are-5-schools-of-thought

Knoll, D. L., & Gill, H. (2011). Antecedents of trust in supervisors, subordinates, and peers. *Journal of Managerial Psychology*, *26*(4), 313–330. doi:10.1108/02683941111124845

Kosslyn, S. M., Ganis, G., & Thompson, W. L. (2001). Neural foundations of imagery. *Nature Reviews. Neuroscience*, *2*(9), 635–642. doi:10.1038/35090055 PMID:11533731

Koste, D., & Haerem, T. (2016). Transactive memory systems in virtual teams: The effect of integration and differentiation on performance. *Academy of Management Annual Meeting Proceedings*, *2016*(1), 1-6.

Krause, J. (2018): Durch Technische Compliance zu mehr Effizienz in der Chlorindustrie. *Vestnik chimičeskoj promyšlennosti,* (102), 18-23.

Krause, J. (2015). *Regulierung von Investitionsprojekten in Russland*. Wiesbaden, Germany: Gabler Springer.

Kress, G., & Van Leeuwen, T. (1996). *Reading Images: The Grammar of Visual Design*. London, UK: Routledge.

Kuckartz, U., Dresing, T., Rädiker, S., & Stefer, C. (2008). *Qualitative Evaluation: Der Einstieg in die Praxis*. Wiesbaden: Springer Verlag.

Küpper, D., Heidemann, A., Ströhle, D., Spindelndreier, D., & Knizek, C. (2017). *When lean meets Industry 4.0: the next level of operational excellence.* Retrievable from https://www.bcg.com/publications/2017/lean-meets-industry-4.0.aspx

Kurzweil, R. (2005). *The Singularity is Near: When Humans Transcend Biology*. Viking Penguin.

Lakoff, G. (2014). Mapping the brain's metaphor circuitry: Metaphorical thought in everyday reason. *Frontiers in Human Neuroscience*, *8*.

Lakoff, G., & Johnson, M. (1980). *Metaphors We Live By*. Chicago: University of Chicago Press.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the Flesh*. New York: Basic Books.

Layman, T. (2010). *Build It and They Will Come*. Retrieved from <http://ngm.nationalgeographic.com/2010/07/bowerbirds/laman-photography>

LearningRx. (2019). *What are cognitive skills?* Retrieved February 4, 2019 https://www.learningrx.com/what-is-brain-training-/what-are-cognitive-skills-/

Lerman, C., Audrain, J., Main, D., Bowman, E. D., Lockshin, B., Boyd, N. R., & Shields, P. G. (1999). Evidence suggesting the role of specific genetic factors in cigarette smoking. *Health Psychology*, *18*(1), 14–20. doi:10.1037/0278-6133.18.1.14 PMID:9925041

Leslie, A. M. (1987). Pretense and Representation: The Origins of "Theory of Mind". *Psychological Review*, *94*(4), 412–426. doi:10.1037/0033-295X.94.4.412

Levine, M. (1987). *Effective problem solving*. Englewood Cliffs, NJ: Prentice Hall.

Lewis, K., Lange, D., & Gillis, L. (2005). Transactive Memory Systems, Learning, and Learning Transfer. *Organization Science*, *16*(6), 581–598. doi:10.1287/orsc.1050.0143

Ley, T., & Seitlinger, P. (2015). Dynamics of human categorization in a collaborative tagging system: How social processes of semantic stabilization shape individual sensemaking. *Computers in Human Behavior*, *51*, 140–151. doi:10.1016/j.chb.2015.04.053 PMID:26566299

Link, J. (1997). *Versuch über den Normalismus. Wie Normalität produziert wird*. Opladen: VS.

Livingston, D. (1973). *Master of Light: A Biography of Albert A. Michelson*. New York, NY: Scribner.

Lohaus, D., & Habermann, W. (2013). *Personalauswahl im Mittelstand. Nicht die Besten sind die Besten, sondern die Geeignetsten*. Munich: Oldenbourg Verlag. doi:10.1524/9783486754087

Lu, H., & Wu, J. (2015, August 09). Taiwan faces brain drain as wage growth slows: report. *Focus Taiwan.* Retrieved January 20. 2019 from http://focustaiwan.tw/news/aeco/201508090014.aspx

Lubart, T. I. (2001). Models of the Creative Process: Past, Present and Future. *Creativity Research Journal*, *13*(3-4), 295–308. doi:10.1207/S15326934CRJ1334_07

Luciano, M., Wright, M. J., Duffy, D. L., Wainwright, M. A., Zhu, G., Evans, D. M., ... Martin, N. G. (2006). Genome-wide scan of IQ finds significant linkage to a quantitative trait locus on 2q. *Behavior Genetics*, *36*(1), 45–55. doi:10.100710519-005-9003-1 PMID:16341610

Luhmann, N. (1974). Einführende Bemerkungen zu einer Theorie symbolisch generalisierter Kommunikationsmedien. *Zeitschrift für Soziologie*, *3*(3), 236–255. doi:10.1515/zfsoz-1974-0303

Luhmann, N. (1986). The Individuality of the Individual: Historical Meanings and Contemporary Problems. In T. C. Heller, M. Sosna, & D. E. Wellbery (Eds.), *Reconstructing Individualism: Autonomy, Individuality, and the Self in Western Thought* (pp. 313–325). Stanford, CA: Stanford University Press.

Luhmann, N. (1990). *Ökologische Kommunikation. Kann die moderne Gesellschaft sich auf ökologische Gefährdungen einstellen?* Opladen: VS.

MacGregor, K. (2013). *A higher education avalanche is coming, says new report.* University World News: The global window on higher education. Retrieved February 4, 2019 from https://www.universityworldnews.com/post.php?story=20130316093956321

Mader, S. S., & Windespecht, M. (2016). *Biology* (12th ed.). New York: McGraw Hill Education.

Maeda, F., Kleiner-Fisman, G., & Pascual-Leone, A. (2002). Motor facilitation while observing hand actions: Specificity of the effect and role of observer's orientation. *Journal of Neurophysiology*, *87*(3), 1329–1335. doi:10.1152/jn.00773.2000 PMID:11877507

Maher, B. (1972). The language of schizophrenia: A review and interpretation. *The British Journal of Psychiatry*, *120*(554), 3–17. doi:10.1192/bjp.120.554.3 PMID:4557434

Majchrzak, A., Malhotra, A., & John, R. (2005). Perceived individual collaboration know-how development through information technology-enabled contextualization: Evidence from distributed teams. *Information Systems Research*, *16*(1), 9–27. doi:10.1287/isre.1050.0044

Marcus, G. E. (1995). *Technoscientific Imaginaries*. Chicago: University of Chicago Press.

Mareis, C., & Joost, G. (Eds.). (2013). Wer gestaltet die Gestaltung? Praxis, Theorie und Geschichte des partizipatorischen Design. Bielefeld: Transcript. doi:10.14361/transcript.9783839420386

Marieb, E. N., & Hoehn, K. (2013). *Human Anatomy and Physiology* (9th ed.). Pearson Education.

Martindale, C. (1971). Degeneration, disinhibition, and genius. *Journal of the History of the Behavioral Sciences*, *7*(2), 177–182. doi:10.1002/1520-6696(197104)7:2<177::AID-JHBS2300070207>3.0.CO;2-N PMID:11609598

Martindale, C. (1977). Creativity, consciousness, and cortical arousal. *Journal of Altered States of Consciousness*, *3*(1), 69–87.

Martindale, C. (1989). Personality, situation and creativity. In J. Glover, R. Ronning, & C. Reynolds (Eds.), *Handbook of creativity*. New York: Plenum. doi:10.1007/978-1-4757-5356-1_13

Martindale, C. (1999). Biological basis of creativity. In R. J. Sternberg (Ed.), *Handbook of creativity*. Cambridge, UK: Cambridge University Press.

Marx, K. (1987). Das Kapital. Kritik der politischen Ökonomie. Erster Band.

Mashal, N., Faust, M., Hendler, T., & Jung-Beeman, M. (2007). An fMRI investigation of the neural correlates underlying the processing of novel metaphoric expressions. *Brain and Language*, *100*(2), 115–126. doi:10.1016/j.bandl.2005.10.005 PMID:16290261

Mason, M. F., Norton, M. I., Van Horn, J. D., Wegner, D. M., Grafton, S. T., & Macrae, C. N. (2007). Wandering Minds: The Default Network and Stimulus-Independent Thought. *Science*, *315*(5810), 393–395. doi:10.1126cience.1131295 PMID:17234951

Matheisen, E. (2017, Mai 22). Whitepaper: Bewerber-Reichweite, Karriere-Webseiten und Jobbörsen. *Jobspreader by wollmilchsau Blog*. Retrieved March 29, 2019 from https://wollmilchsau.de/personalmarketing/bewerber-reichweite/

Matheisen, E. (2017, May 3). Webseiten deutscher Industrieunternehmen – Ankunft im digitalen Zeitalter? *Jobspreader by wollmilchsau Blog*. Retrieved March 29, 2019 from https://wollmilchsau.de/karrierewebseiten/webseiten-deutscher-industrieunternehmen-ankunft-im-digitalen-zeitalter/

Matherne, S. (2016). Kant's theory of the imagination. In A. Kind (Ed.), *The Routledge Handbook of Philosophy of Imagination*. New York: Routledge.

Mattgey, A. (2014, October 23). Bunte Gen Y: Von taffen Machern und schlaffen Followern. *W&V Studie*. Retrieved March 16, 2019 from https://www.wuv.de/karriere/bunte_gen_y_von_taffen_machern_und_schlaffen_followern

Matzler, K., Bailom, F., & Mooradian, T. A. (2007). Intuitive decision-making. *MIT Sloan Management Review*, *49*(2), 2–15.

Mazor, A. (2017). The employee experience: Culture, engagement, and beyond. 2017 *Deloitte global human capital trends*. Retrieved May 06, 2019 from https://trendsapp.deloitte.com/reports/2017/global-human-capital-trends/the-employee-experience.html

McAfee, A., Brynjolfsson, E., Davenport, T. H., Patil, D. J., & Barton, D. (2012). Big data: The management revolution. *Harvard Business Review*, *90*(10), 60–68. PMID:23074865

McCurdy, H. (1997). *Space and the American imagination*. Washington, DC: Smithsonian Institution Press.

McNamara, P., Nunn, C., Barton, R., Harris, E., & Capellini, I. (2007). Phylogeny of Sleep and Dreams. In D. Barrett & P. McNamara (Eds.), *The New Science of Dreaming* (Vol. 1). Westport, CT: Praeger.

Meadows, D. (1987). Die Grenzen des Wachstums (H-D. Heck, Trans.; 14th ed.). Stuttgart: Deutsche Verlags-Anstalt.

Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review*, *69*(3), 220–232. doi:10.1037/h0048850 PMID:14472013

Meier, F. (2013, September 01). HR in KMU. *HR Today.* Retrieved April 01, 2019 from http://www.steck-hr.ch/docs/S.15-19K_ThemaEinleitungInti9_13.pdf

Meister, J. (2012). The Future Of Work: Corporate Social Responsibility Attracts Top Talent. *Forbes.* Retrieved February 16, 2019 from https://www.forbes.com/sites/jeannemeister/2012/06/07/the-future-of-work-corporate-social-responsiblity-attracts-top-talent/#77ccbd3f954d

Meyer, N., & Reguant-Closa, A. (2017). >Eat as if you could save the planet and win!< sustainability integration into nutrition for exercise and sport. *Nutrients*, *9*(4), 412. doi:10.3390/nu9040412 PMID:28430140

Michaud, T. (2008). *Télécommunications et science-fiction*. Paris: Editions Memoriae.

Michaud, T. (2010). *La stratégie comme discours, la science-fiction dans les centres de recherche et développement*. Paris: L'Harmattan.

Michaud, T. (2017). *Innovation, between science and science fiction*. Wiley. doi:10.1002/9781119427568

Michaud, T. (2018). *La réalité virtuelle, de la science-fiction à l'innovation*. L'Harmattan.

Milgrim, R. M., Hong, E., Shavit, Y. W., & Peled, R. W. (1997). Out of School Activities in Gifted Adolescents as a Predictor of Vocational Choice and Work Accomplishment in Young Adults. *Journal of Secondary Gifted Education*, *8*(3), 111–120. doi:10.1177/1932202X9700800303

Mitchell, W. J. T. (1992). The Pictorial Turn. In Artforum. Hamburg, Germany: Rowohlt.

Mitchell, R. W. (2012). Self-Recognition in Animals. In M. R. Leary & J. Tangney (Eds.), *Handbook of Self and Identity* (2nd ed.). New York: Guilford Press.

Mitchell, R., & Nicholas, S. (2006a). Knowledge creation through boundary-spanning. *Knowledge Management Research and Practice*, *4*(4), 310–318. doi:10.1057/palgrave.kmrp.8500113

Mitchell, R., & Nicholas, S. (2006b). Knowledge Creation in Groups: The Value of Cognitive Diversity, Transactive Memory and Open-mindedness Norms. *Electronic Journal of Knowledge Management*, *4*(1), 67–74.

Mithen, S. (1996). *The prehistory of the mind: The cognitive origins of art and science*. London, UK: Thames and Hudson.

Mithen, S. (2008). Seven Steps in the Evolution of the Human Imagination. In I. Roth (Ed.), *Imaginative Minds*. Oxford, UK: Oxford University Press.

Mithen, S. J. (2005). *The Singing Neanderthal: The Origins of Music, Language, Mind and Body*. London: Weidenfeld and Nicolson.

MM/ Maschinenmarkt. (2013). *Blue Competence Kodex für Nachhaltigkeit im Maschinenbau beschlossen.* Retrieved from https://www.wiso-net.de/document/MAMA__381513500

Modell, A. (2003). *Imagination and the meaningful brain*. Cambridge, MA: MIT Press. doi:10.7551/mitpress/3666.001.0001

Mortensen, D. (2017). *Automation may take our jobs – but it'll restore our humanity*. Retrievable from https://qz.com/1054034/automation-may-take-our-jobs-but-itll-restoreour-humanity

Moss, R. (2015). *Creative AI: The robots that would be painters*. Retrieved from: https://newatlas.com/creative-ai-algorithmic-art-painting-fool-aaron/36106/

Mouton, J. (2001). *How to succeed in your master's and doctoral studies*. Pretoria: Van Schaik.

Muff, K. (2013). Developing globally responsible leaders in business schools. *Journal of Management Development*, *32*(5), 487–507. doi:10.1108/02621711311328273

Nagle, T., Redman, T. C., & Sammon, D. (2017). *Only 3% of companies' data meets basic quality standards.* Retrievable from https://hbr.org/2017/09/only-3-of-companies-datameets-basic-quality-standards

Natarajan, G. (2018). *Knowledge management and big data.* New Delhi: Confederation of Indian Industry.

Neckel, S. (2018). Ökologische Distinktion. Soziale Grenzziehung im Zeichen von Nachhaltigkeit. In S. Neckel (Eds.), Die Gesellschaft der Nachhaltigkeit. Umrisse eines Forschungsprogramms (pp. 59-76). Bielefeld: Transcript.

Neisser, U. (1967). *Cognitive psychology*. Englewood Cliffs, NJ: Prentice Hall.

Nemeth, C. J., & Nemeth-Brown, B. (2003). Better than individuals? The potential benefits of dissent and diversity for group creativity. In P. B. Paulus (Ed.), Group creativity: Innovation through collaboration, (pp. 63-84). London: Oxford University Press.

Neuroscience News. (2019). *How the Brain Learns New Skills.* Retrieved February 4, 2019 from https://neurosciencenews.com/skill-learning-brain-13013/

Newell, A., & Simon, H. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice Hall.

Newsroom. (2019). *Ken Robinson has a theory: School kills creativity (and it must be changed).* Retrieved February 4, 2019 https://www.morningfuture.com/en/article/2019/02/06/ken-robinson-creativity-school/538/

Novitz, D. (1999). Creativity and constraint. *Australasian Journal of Philosophy*, *77*(1), 71–78. doi:10.1080/00048409912348811

Nuez, R. B. (2018). *By 2020 your skills will be unimportant but why*? Retrieved January 30, 2019 from https://medium.com/@ramonbnuezjr/by-2020-your-skills-will-be-unimportant-but-why-641d1cf3a1ee

O'Connell, J. F., Hawkes, K., & Blurton-Jones, N. G. (1999). Grandmothering and the evolution of Homo erectus. *Journal of Human Evolution*, *36*(5), 461–485. doi:10.1006/jhev.1998.0285 PMID:10222165

O'Dell, C. (2018). *How to future proof your KM effort: insights from APQC KM expert Carla O'Dell*. Houston, TX: APQC.

Obach, B. K. (2009). Consumption, ecological footprints and global inequality: A lesson in individual and structural components of environmental problems. *Teaching Sociology*, *37*(3), 294–300. doi:10.1177/0092055X0903700307

Ochse, R. (1990). *Before the gates of excellence: The determinants of creative genius*. New York: Cambridge University Press.

OECD. (2019). *Average usual weekly hours worked on the main job*. OECD. Retrieved April 30, 2019 from https://stats.oecd.org/Index.aspx?DatasetCode=STLABOUR

Ooms, W., Werker, C., & Caniels, M. (2018). Personal and Social Proximity Empowering Collaborations: The Glue of Knowledge Networks. *Industry and Innovation*, *25*(9), 833–840. doi:10.1080/13662716.2018.1493983

OpenStax. (2016). *The neuron*. Retrieved from Wikipedia wiki: https://commons.wikimedia.org/wiki/File:1206_The_Neuron.jpg

Osborn, A. (1953). *Applied Imagination*. New York: Charles Scribner.

Osborn, A. F. (1953). *Applied imagination*. New York: Scribners.

Paik, P. Y. (2010). *From utopia to apocalypse: science fiction and the politics of catastrophe*. University of Minnesota Press. doi:10.5749/minnesota/9780816650781.001.0001

Paivio, A. (1971). *Imagery and verbal processes*. New York, NY: Holt, Rinehart & Winston.

Paivio, A. (1978). A dual coding approach to perception and cognition. In H. L. Pick & E. Saltzmann (Eds.), *Modes of perceiving and processing information* (pp. 39–52). Hillsdale, NJ: Erlbaum.

Paivio, A. (1986). *Mental representations: a dual coding approach*. Oxford, UK: Oxford University.

Parker, M. (Ed.). (1992). *Utopia and Organization*. Oxford, UK: Blackwell.

Parment, A. (2009). *Die Generation Y - Mitarbeiter der Zukunft. Herausforderung und Erfolgsfaktor für das Personalmanagement*. Wiesbaden: Gabler. doi:10.1007/978-3-8349-8802-7

Patrick, C. (1935). Creative thought in poets. *Archives de Psychologie*, *178*, 1–74.

Patrick, C. (1937). Creative thought in artists. *The Journal of Psychology*, *4*(1), 35–73. doi:10.1080/00223980.1937.9917525

Patrick, C. (1938). Scientific thought. *The Journal of Psychology*, *5*(1), 55–83. doi:10.1080/00223980.1938.9917552

Patuzzo, S., Fiaschi, A., & Manganotti, P. (2003). Modulation of motor cortex excitability in the left hemisphere during action observation: A single and paired-pulse transcranial magnetic stimulation study of self- and non-self action observation. *Neuropsychologia*, *41*(9), 1272–1278. doi:10.1016/S0028-3932(02)00293-2 PMID:12753966

Penprase, B. E. (2019). The Fourth Industrial Revolution and Higher Education. In N. W. Gleason (Ed.), *Higher education in the era of the Fourth Industrial Revolution* (pp. 216–228). Singapore: Palgrave Macmillan.

Peschel, A. O., Grebitus, C., Steiner, B., & Veeman, M. (2016). How does consumer knowledge affect environmentally sustainable choices? Evidence from a cross-country latent class analysis of food labels. *Appetite*, *106*, 78–91. doi:10.1016/j.appet.2016.02.162 PMID:26944229

Petersen, T., & Schwender, C. (2011). *Die Entschlüsselung der Bilder. Methoden zur Erforschungvisueller Kommunikation. Ein Handbuch*. Köln, Germany: Herbert von Halem.

Petrone, P. (2019, January 1). *Why creativity is the most important skill in the world*. [LinkedIn The Learning Blog]. Retrieved February 4, 2019 from https://learning.linkedin.com/blog/top-skills/why-creativity-is-the-most-important-skill-in-the-world

Pink, S. (2012). Advances in Visual Methodology: An Introduction. In S. Pink (Ed.), *Advances inVisual Methodology* (pp. 3–16). London, UK: Sage. doi:10.4135/9781446250921.n1

Planck, M. (1949). *Scientific Autobiography and Other Papers* (F. Gaynor, Trans.). New York, NY: Philosophical Library. (Original work published 1948)

Polanyi, M. (1985). *Implizites Wissen*. Frankfurt, Germany: Suhrkamp.

Polland, M. J. (1996). *Mental Imagery in Creative Problem Solving* (Doctoral Dissertation). Retrieved from https://files.eric.ed.gov/fulltext/ED393593.pdf

PricewaterhouseCoopers & World Economic Forum. (2017). *Fourth Industrial Revolution for the Earth: Harnessing the 4th Industrial Revolution for Sustainable Emerging Cities*. Retrieved from: https://www.pwc.com/gx/en/sustainability/assets/4ir-for-the-earth.pdf

PricewaterhouseCoopers (PwC network). (2018). *Workforce of the future - The competing forces shaping 2030*. Retrieved February 4, 2019 from https://www.pwc.com/gx/en/services/people-organisation/workforce-of-the-future/workforce-of-the-future-the-competing-forces-shaping-2030-pwc.pdf

PricewaterhouseCoopers (PwC network). (2019). *Talent trends 2019: Upskilling for a digital world*. Part of PwC's 22nd Annual Global CEO Survey Trends Series. Retrieved February 4, 2019 from https://www.pwc.com/gx/en/ceo-agenda/ceosurvey/2019/themes/talent-trends.html

Prosser, J. (1998). *Image-based Research. A Sourcebook for Qualitative Researchers*. London, UK: Routledge.

Prosser, J. (2006). What Constitutes an Image-based Methodology? In P. Hamilton (Ed.), *VisualResearch Methods*. London, UK: Sage.

Pushpa, R. (2019). *Artificial intelligence and knowledge management: understanding how they are linked.* Retrieved from https://www.linkedin.com/pulse/artificial-intelligence-knowledge-management-how-linked-pushpa/

Radermacher, S. (2013). Die Herausforderungen des Employer Brandings. In H. Künzel (Ed.), *Erfolgsfaktor Employer Branding. Mitarbeiter binden und die Gen Y gewinnen* (pp. 1–16). Berlin: Springer-Verlag. doi:10.1007/978-3-642-40535-8_1

Raichle, M. E. (2015). The brain's default mode network. *Annual Review of Neuroscience*, *38*(1), 433–447. doi:10.1146/annurev-neuro-071013-014030 PMID:25938726

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences of the United States of America*, *98*(2), 676–682. doi:10.1073/pnas.98.2.676 PMID:11209064

Rawlings, D., & Locarnini, A. (2008). Dimensional schizotypy, autism, and unusual word associations in artists and scientists. *Journal of Research in Personality*, *42*(2), 465–471. doi:10.1016/j.jrp.2007.06.005

Raworth, K. (2017). *Doughnut Economics. Seven ways to think like a 21st-Cebntury Economist*. London, UK: Cornestone.

Razumnikova, O. M., & Larina, E. N. (2005). Hemispheric interactions during the search for novel verbal analogies: Particularities of brain potentials' coherence in creative men and women. *I. P. Pavlov Journal of Higher Nervous Activity Names*, *55*(6), 785–795.

Reagans, R. (2011). Close encounters: Analyzing how social similarity and propinquity contribute to strong network connections. *Organization Science*, *22*(4), 835–849. doi:10.1287/orsc.1100.0587

Reavey, P. (Ed.). (2011). Visual methods in psychology. Using and interpreting images in qualitativeresearch. Hove, UK: Psychology Press; Routledge.

Rehm, F. (2014). *Web 2.0 im Bereich der Personalbeschaffung*. Munich: Rainer Hampp Verlag.

Ren, Y., & Argote, L. (2011). Transactive memory systems 1985-2010: An integrative framework of key dimensions, antecedents, and con-sequences. *The Academy of Management Annals*, *5*(1), 189–229. doi:10.1080/19416520.2011.590300

Ribeiro Novo Melo, P., & Machado, C. F. (2014). *HRM Evolution in SMEs: Recruitment and Selection Case*. Hershey, PA: IGI Global.

Richardson, R. B. (2013). *Building a green economy. Perspectives from ecological economics*. East Lansing, MI: Michigan State University Press.

Richards, R. (Ed.). (2007). *Everyday creativity and new views of human nature: Psychological, social, and spiritual perspectives* (p. 349). Washington, DC: American Psychological Association. doi:10.1037/11595-000

Richards, R., Kinney, D. K., Lunde, I., Benet, M., & Merzel, A. P. C. (1988). Creativity in manic—Depressives, cyclothymes, their normal relatives, and control subjects. *Journal of Abnormal Psychology*, *97*(3), 281–288. doi:10.1037/0021-843X.97.3.281 PMID:3192819

Richert, A., Shehadeh, M., Plumanns, L., Groß, K., Schuster, K., & Jeschke, S. (2016, April). Educating engineers for industry 4.0: Virtual worlds and human-robot-teams: Empirical studies towards a new educational age. In *2016 IEEE Global Engineering Education Conference (EDUCON)* (pp. 142-149). IEEE. 10.1109/EDUCON.2016.7474545

Rizzolatti, G., & Craighero, L. (2004). The Mirror-Neuron System. *Annual Review of Neuroscience*, *27*(1), 169–192. doi:10.1146/annurev.neuro.27.070203.144230 PMID:15217330

Rizzolatti, G., Fabbri-Destro, M., & Cattaneo, L. (2009). Mirror neurons and their clinical relevance. *Nature Clinical Practice. Neurology*, *5*(1), 24–34. doi:10.1038/ncpneuro0990 PMID:19129788

Robey, D., Khoo, H. M., & Powers, C. (2000). Situated learning in cross-functional virtual teams. *IEEE Transactions on Professional Communication*, *43*(1), 51–66. doi:10.1109/47.826416

Rodriguez, J. (2016). *AI and the Human Brain: Creativity and Imagination*. Retrieved from: https://medium.com/@jrodthoughts/ai-and-the-human-brain-creativity-and-imagination-56ca99198d06

Roe, B. E., Tilley, M. R., Gu, H. H., Beversdorf, D. Q., Sadee, W., Haab, T. C., & Papp, A. C. (2009). Financial and psychological risk attitudes associated with two single nucleotide polymorphisms in the nicotine receptor (CHRNA4) gene. *PLoS One*, *4*(8), e6704. doi:10.1371/journal.pone.0006704 PMID:19693267

Rogers, Y., & Ellis, J. (1994). Distributed Cognition: An alternative framework for analysing and explaining collaborative working. *Journal of Information Technology*, *9*(2), 119–128. doi:10.1177/026839629400900203

Root-Bernstein, R. S. (2006). Art Science: The Essential Connection, Albert Michelson, Painter of Light. *Leonardo*, *39*(3), 232. doi:10.1162/leon.2006.39.3.232

Root-Bernstein, R. S., Allen, L., Beach, L., Bhadula, R., Fast, J., Hosey, C., ... Weinlander, S. (2008). Arts Foster Scientific Success: Avocations of Nobel, National Academy, Royal Society, and Sigma Xi Members. *Journal of Psychology of Science and Technology*, *1*(2), 51–63. doi:10.1891/1939-7054.1.2.51

Root-Bernstein, R. S., Bernstein, M. M., & Garnier, H. (1995). Correlations between Avocations, Scientific Style, Work Habits, and Professional Impact of Scientists. *Creativity Research Journal*, *8*(2), 115–137. doi:10.120715326934crj0802_2

Root-Bernstein, R. S., Bernstein, M., & Garnier, H. (1993). Identification of Scientists Making Long-Term High-Impact Contributions, with Notes on Their Methods of Working. *Creativity Research Journal*, *6*(4), 329–343. doi:10.1080/10400419309534491

Root-Bernstein, R. S., & Root-Bernstein, M. M. (2004). Artistic Scientists and Scientific Artists: The Link between Polymathy and Creativity. In R. J. Sternberg, E. L. Grigorenko, & J. L. Singer (Eds.), *Creativity: From Potential to Realization* (pp. 127–151). Washington, DC: American Psychological Association. doi:10.1037/10692-008

Root-Bernstein, R., Pathak, A., & Root-Bernstein, M. (2017). (Accepted)). A Review of ACD-STEMM Integration, Part 3: Controlled Studies of Additional Transdisciplinary Bridges for Arts-Science Pedagogy and General Conclusions. *Leonardo*. *Just*, 1–3.

Root-Bernstein, R., Van Dyke, M., Peruski, A., & Root-Bernstein, M. (2019, February 5). Correlation between tools for thinking; arts, crafts, and design avocations; and scientific achievement among STEMM professionals. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(6), 1910–1917. doi:10.1073/pnas.1807189116 PMID:30718388

Rosen, M., Pucaciarelli, J.C., Findling, S., Hand, L., Segal, R., Anderson, C., … Kolding, M. (2017). *How the digital-native enterprise is winning the future, now*. Farmingham: IDC.

Rossman, J. (1931). *The psychology of the inventor*. Washington, DC: Inventors Publishing.

Rossouw, D. (Ed.). (2014). *Intellectual tools: Skills for the human sciences* (2nd ed.). Pretoria: Van Schaik Publishers.

Runco, M. A. (2004). Everyone has creative potential. In R. J. Sternberg, E. L. Grigorenko, & J. L. Singer (Eds.), *Creativity: From potential to realization*. Washington, DC: American Psychological Association. doi:10.1037/10692-002

Ruthus, J. (2013). *Employer of Choice der Generation Y. Herausforderungen und Erfolgsfaktoren zur Steigerung der Arbeitgeberattraktivität*. Wiesbaden: Gabler. doi:10.1007/978-3-658-04734-4

Ruthus, J. (2014). *Arbeitgeberattraktivität aus Sicht der Generation Y. Handlungsempfehlungen für das Human Resources Management*. Wiesbaden: Gabler.

Ryan, R., & Deci, E. (2000). Intrinsic and extrinsic motivations. Classical definitions and new directions. *Contemporary Educational Psychology*, *25*(1), 54–67. doi:10.1006/ceps.1999.1020 PMID:10620381

Ryle, G. (1949). *The Concept of Mind*. New York: Barnes & Noble.

Sachs-Hombach, K. (1993). *Das Bild als kommunikatives Medium. Elemente einer allgemeinen Bildwissenschaft*. Köln, Germany: Herbert von Halem.

Sächsisches Staatsministerium für Wirtschaft, Arbeit und Verkehr. (2013, Dezember 9). *Mittelstandsbericht 2011/2012*. Dresden: Land Sachsen.

Sächsisches Staatsministerium für Wirtschaft, Arbeit und Verkehr. (2016a). Mittelstandsbericht 2013/2014. Dresden: Land Sachsen.

Sächsisches Staatsministerium für Wirtschaft, Arbeit und Verkehr. (2016b). Standort Sachsen im Vergleich mit anderen Regionen. Dresden: Land Sachsen.

SAKAN. (n.d.). *South Africa's Fourth Industrial Revolution*. Retrieved from: http://www.sakan.org.za/4IR.html

Sawyer, K. (2013). *Zig Zag: The surprising path to greater creativity*. San Francisco, CA: Jossey-Bass.

Schiller, S. Z., & Mandviwalla, M. (2007). Virtual Team Research: An Analysis of Theory Use and a Framework for Theory Appropriation. *Small Group Research*, *38*(1), 12–59. doi:10.1177/1046496406297035

Schmidt, I. (2016). *Consumer Social Responsibility. Gemeinsame Verantwortung für nachhaltiges Konsumieren und Produzieren*. Wiesbaden: Springer VS.

Scholes, R. E. (1994). Structural fabulation: an essay on fiction of the future. UMI.

Schütz, A. (1962). *Collected papers I: The problem of Social reality, part I*. Amsterdam, Netherlands: Martinus-Nijhoff.

Schütz, A. (1971). *Gesammelte Aufsätze: I Das Problem der sozialen Wirklichkeit*. Den Haag, Netherlands: Martinus Nijhoff.

Schwab, K. (2016). *The fourth industrial revolution.* Cologne: World Economic Forum.

Schwab, K. (2016). *The fourth industrial revolution*. Cologny: World Economic Forum.

Schwab, K. (2017). *The fourth industrial revolution*. London, UK: Portfolio Penguin.

Schwab, K. (2018). *The Future of the Fourth Industrial Revolution*. London: Penguin Books.

Schwab, K., Davis, N., & Nadella, S. (2018). *Shaping the Future of the Fourth Industrial Revolution*. New York, NY: Currency.

Science of Summit. (2019). *The Science of Summit Report 2018*. Retrieved February 4, 2019 from https://valley.aspenps.org/pdfs/2018_science_of_summit_2.pdf

Seagoe, M. (1975). *Terman and the Gifted.* Kaufmann.

Semaw, S., Renne, P., Harris, J. W. K., Feibel, C. S., Bernor, R. L., Fesseha, N., & Mowbray, K. (1997). 2.5-million-year-old stone tools from Gona, Ethiopia. *Nature*, *385*(6614), 333–336. doi:10.1038/385333a0 PMID:9002516

Senge, P. M. (1990). *The fifth discipline: The art and practice of the learning organization*. New York, NY: Doubleday.

Sepper, D. L. (2016). Descartes. In A. Kind (Ed.), *The Routledge Handbook of Philosophy of Imagination*. New York: Routledge.

Shaler-Shwartz, S., & Ben-David, S. (2014). *Understanding machine learning*. Cambridge, MA: Cambridge University Press. doi:10.1017/CBO9781107298019

Shedroff, N., & Noessel, C. (2012). *Make it so: Interaction design lessons from science fiction*. New York: Rosenfeld Media. doi:10.1145/2254556.2254561

Siebdrat, F., Hoegl, M., & Ernst, H. (2009). How to manage virtual teams. *MIT Sloan Management Review*, *50*(4), 63–68.

Siegrist, H., Kaelble, H., & Kocka, J. (Eds.). (1997). *Europäische Konsumgeschichte. Zur Gesellschafts- und Kulturgeschichte des Konsums (18. bis 20. Jahrhundert)*. Frankfurt am Main: Campus.

Siemsen, E., Roth, A. V., Balasubramanian, S., & Anand, G. (2009). The Influence of Psychological Safety and Confidence in Knowledge on Employee Knowledge Sharing. *Manufacturing & Service Operations Management: M & SOM*, *11*(3), 429–447. doi:10.1287/msom.1080.0233

Simmel, G. (1997). Sociology of the Meal. In D. P. Frisby & M. Featherstone (Eds.), *Simmel on Culture. Selected writings* (pp. 130–137). London: Sage. (Original work published 1910)

Smith, S. M. (1995a). Fixation, incubation, and insight in memory and creative thinking. In S. M. Smith, T. M. Ward, & R. A. Finke (Eds.), *The creative cognition approach*. Cambridge, MA: MIT Press.

Smith, S. M. (1995b). Getting into and out of mental ruts: A theory of fixation, incubation, and insight. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight*. Cambridge, MA: MIT Press.

Snow, C. P. (1964). *The Two Cultures: and A Second Look*. London: Cambridge University Press.

Soffel, J. (2016). *What are the 21st-century skills every student needs?* World Economic Forum. Retrieved February 4, 2019 from https://www.weforum.org/agenda/2016/03/21st-century-skills-future-jobs-students/

Sole, D., & Applegate, L. (2000). Knowledge Sharing Practices and Technology Use Norms in Dispersed Development Teams. *International Conference on Information Systems*.

Soler, M., Pérez-Contreras, T., & Peralta-Sánchez, J. M. (2014, January 27). Mirror-Mark Tests Performed on Jackdaws Reveal Potential Methodological Problems in the Use of Stickers in Avian Mark-Test Studies. *PLoS One*, *9*(1), e86193. doi:10.1371/journal.pone.0086193 PMID:24475085

Spencer, S. (2011). *Visual research methods in the social sciences. Awakening visions*. London, England: Routledge.

Spreng, R. N., & Schacter, D. L. (2012). Default network modulation and large-scale network interactivity in healthy young and old adults. *Cerebral Cortex*, *22*(11), 2610–2621. doi:10.1093/cercor/bhr339 PMID:22128194

Statisches Landesamt des Freistaates Sachsen. (2015a, September 8). *6. Regionalisierte Bevölkerungsvorausberechnung für den Freistaat Sachsen 2015 bis 2030.* Retrieved April 29, 2019 from https://www.statistik.sachsen.de/download/080_RegBevPrognose_RegEinheiten-PDF/PROG_L_Sachsen_14.pdf

Statisches Landesamt des Freistaates Sachsen. (2015b, September 4). *Geburten und Sterbefälle*. Retrieved April 29, 2019 from http://www.statistik.sachsen.de/html/829.htm

Statisches Landesamt des Freistaates Sachsen. (2017a). *2. Sächsische Wanderungsanalyse. Ergebnisbericht*. Retrieved April 30, 2019 from https://www.statistik.sachsen.de/download/080_SchsWanderungsanalyse/2.SWA_Ergebnisbericht_k.pdf

Statisches Landesamt des Freistaates Sachsen. (2017b, September 30). *Bevölkerungsstand des Freistaates Sachsen nach Kreisfreien Städten und Landkreisen*. Retrieved May 02, 2019 from https://www.statistik.sachsen.de/download/100_Berichte-A/A_I_1_vj3_17_SN.pdf

Statista. (2019). *Countries with the lowest fertility rates in 2017.* Retrieved April 30. 2019 from http://www.statista.com/statistics/268083/countries-with-the-lowest-fertility-rates/

Statista. (n.d.). *Number of people who practiced photography within the last 12 months in the United States from spring 2008 to spring 2017 (in millions)*. Retrieved October 30, 2017 from https://www.statista.com/statistics/227424/number-of-photographers-usa/

Statistical Bureau, Republic of Taiwan. (2015a, September 10). Manpower Utilization Survey. Retrieved from Table 4. Methods Employed Persons Used to Get Current Jobs, by Year. *National Statistics.* Retrieved April 25, 2019 from http://eng.stat.gov.tw/ct.asp?xItem=37191&CtNode=1659&mp=5

Statistical Bureau, Republic of Taiwan. (2015b, September 11). *Social Indicators 2013. National Statistics*. Retrieved April 25, 2019 from http://eng.stat.gov.tw/public/Attachment/410184513VTN8S5UB.pdf

Statistical Bureau, Republic of Taiwan. (2017). *Yearbook of Earnings and Productivity Statistics. National Statistics*. Retrieved April 25, 2019 from https://eng.stat.gov.tw/ct.asp?mp=5&xItem=42941&ctNode=6235

Stein, M. I. (1974). *Stimulating creativity: Individual procedures*. New York: Academic.

Steinmetz, C. (2018). *How does a city get to be 'smart? This is how Tel Aviv did it*. Retrieved from https://theconversation.com/how-does-a-city-get-to-be-smart-this-is-how-tel-avivdid-it-94898

Stüer, C., Hüsig, S., & Biala, S. (2010). Integrating Art as a Trans-Boundary Element in a Radical Innovation Framework. *R & D Management*, *40*(1), 10–18. doi:10.1111/j.1467-9310.2009.00581.x

Suri, R. (2018). *The Fourth Industrial Revolution will bring a massive productivity boom*. World Economic Forum. Retrieved February 4, 2019 from https://www.weforum.org/agenda/2018/01/fourth-industrial-revolution-massive-productivity-boom-good/

Sutton, R., & Hargadon, A. B. (1996). Brainstorming groups in context: Effectiveness in a product design firm. *Administrative Science Quarterly*, *41*(4), 685–718. doi:10.2307/2393872

Taiwan, A. H. K. (2019). *Taiwan: Smart, Innovative, Green*. Retrieved April 30, 2019 from https://taiwan.ahk.de/country-info/taiwan-smart-innovative-green/

Takenaka, H. (2018). *Making Japan a major force in the Fourth Industrial Revolution*. Retrieved from: https://www.japantimes.co.jp/opinion/2018/04/02/commentary/japan-commentary/making-japan-major-force-fourth-industrial-revolution/#.XL8A2JgzbIV

Taylor, I. A. (1959). The nature of the creative process. In P. Smith (Ed.), *Creativity: An examination of the creative process*. New York: Hastings House.

Taylor, I. A., Austin, G. A., & Sutton, D. F. (1974). A note on "instant creativity" at CPSI. *The Journal of Creative Behavior*, *8*(3), 208–210. doi:10.1002/j.2162-6057.1974.tb01126.x

Tenbruck, F. (1965). *Jugend und Gesellschaft*. Freiburg im Breisgau: Rombach.

Tesla, N. (1919). *The Autobiography of Nikola Tesla*. New York, NY: Experimenter Publishing Company, Inc.

Thompson, A. L., & Klatzky, R. L. (1978). Studies of visual synthesis: Integration of fragments into forms. *Journal of Experimental Psychology. Human Perception and Performance*, *4*(2), 244–263. doi:10.1037/0096-1523.4.2.244 PMID:660099

Timperley, B. (2018). How soon are robots going to steal our jobs. *Business Report.*, *8*, 1–22.

Trainers Warehouse. (2019). *Zig Zag Creativity Cards*. Retrieved February 4, 2019 from https://www.trainerswarehouse.com/zig-zag-creativity-cards.html

Trees, L. (2015). *How technology will affect the future of Knowledge Management*. Retrieved from https://www.apqc.org/blog/how-technology-will-affect-future-knowledgemanagement

Turak, A. (2011). *Can Creativity Be Taught?* Forbes Leadership. Retrieved February 4, 2019 from https://www.forbes.com/sites/augustturak/2011/05/22/can-creativity-be-taught/#7af2fe761abb

Van Dam, N. H. M. (2017). *The 4th Industrial Revolution & the Future of Jobs*. Copenhagen: Bookboon.

Van der Spek, R., Hofer-Alfeis, J., & Kingma, J. (2003). The Knowledge Strategy Process. In C. W. Holsapple (Ed.), *Handbook on Knowledge Management* (pp. 443–466). Berlin: International Handbooks on Information Systems. doi:10.1007/978-3-540-24748-7_20

Van Herreweghe, M. (2015). *The 4th Industrial Revolution: opportunity and imperative: evolution for some, revolution for others.* IDC Manufacturing Insights White paper.

Van Maanen, J. (1979). *Qualitative methodology*. Beverly Hills, CA: Sage Publications.

Vance, R. (2006). *Employee Engagement and Commitment*. Retrieved May 05, 2019 from: https://www.shrm.org/hr-today/trends-and-forecasting/special-reports-and-expert-views/Documents/Employee-Engagement-Commitment.pdf

Vanderah, T., & Gould-Nolte, D. (2015). *Nolte's The Human Brain: An Introduction to its Functional Anatomy* (7th ed.). Philadelphia, PA: Elsevier.

Vandervelde, W. (2018). *When the box is the limit: Drive your creativity with constraints*. Amsterdam: BIS Publishers.

VDI. (2012). Maschinenbauer wollen durch Nachhaltigkeit punkten. *VDI Nachrichten*. Retrieved from https://www.wiso-net.de/document/VDIN__522444

Veblen, T. (1994). *The Theory of the Leisure Class: An Economic Study of Institutions*. New York: Penguin Books.

Venkitachalam, K., & Willmott, H. (2017). Strategic knowledge management: Insights and pitfalls. *International Journal of Information Management*, *37*(4), 313–316. doi:10.1016/j.ijinfomgt.2017.02.002

Vinacke, W. E. (1952). *The psychology of thinking*. New York: McGraw-Hill.

Visalberghi, E., & Fragaszy, D. (2001). Do monkeys ape? Ten years after. In K. Dautenhahn & C. Nehaniv (Eds.), *Imitation in Animals and Artifacts*. Boston, MA: MIT Press.

Wackernagel, M., & Rees, W. (1996). *Our ecological footprint. Reducing human impact on the earth*. Gabriola Island, BC: New Society Publishers.

Wakefield, H., & Underwager, R. (1998). The Application of Images in Child Abuse Investigations. In J. Prosser (Ed.), *Image-based Research, A Sourcebook for Qualitative Researchers* (pp. 176–194). London, UK: Routledge.

Waldenfels, B. (1999). *Sinnesschwellen. Studien zur Phänomenologie des Fremden 3*. Frankfurt am Main, Germany: Suhrkamp.

Wallas, G. (1926). *The art of thought*. New York: Harcourt Brace.

Walter, A., & Förster, S. (2015, September 10). Befragung von Studierenden der Westsächsischen Hochschule Zwickau 2014. *FOKUS Prints 04/2015.* Retrieved May 05, 2019 from https://www.tu-chemnitz.de/wirtschaft/bwl6/Materialien/WWW_Publikation/FOKUS-Print_04_15.pdf

Walton, K. L. (1990). *Mimesis as Make-Believe: On the Foundations of the Representational Arts*. Cambridge, MA: Harvard University Press.

Wegner, D. M. (1987). Transactive memory: A contemporary analysis of the group mind. In B. Mullen & G. R. Goethals (Eds.), Theories of group behaviour, (pp. 185-208). New York: Springer-Verlag. doi:10.1007/978-1-4612-4634-3_9

Wehner, R., & Menzel, R. (1990). Do Insects have Cognitive Maps? *Annual Review of Neuroscience*, *13*(1), 403–414. doi:10.1146/annurev.ne.13.030190.002155 PMID:2183682

Weick, K.E. (1995). *Sensemaking in organizations*. Sage Publications.

Weick, K. E. (1979). *The social psychology of organizing*. New York: McGraw-Hill.

Weinrich, K. (2015). *Nachhaltigkeitsorientierte Unternehmensführung. Employer Branding als Ansatz zur Gewinnung geeigneter Mitarbeiter*. Wiesbaden: Gabler.

Weisberg, R. W. (1986). *Creativity: Genius and other myths*. New York: Freeman.

Weka Business Medien Gmb, H. (2003). *Internationale Harmonisierung*. Scope. Retrieved from https://www.wiso-net.de/document/SCOP__SCOP20030401182329142723102918242310211417 1027222423

Weller, A. (2018). *Das bildnerische Interview. Zur visualisierten Ordnung der Lebenswelt*. Chemnitz, Germany: TU Chemnitz.

Weller, A., & Bucher, J. (2016). Visualisierte Imaginationen der Lebenswelt und der Einfluss der Medien. In J. Raab & R. Keller (Eds.), *Wissensforschung – Forschungswissen. Beiträge und Debatten zum 1. Sektionskongress der Wissenssoziologie* (pp. 595–607). Weinheim, Germany: Beltz Juventa.

Westfahl, G. (1998). The mechanics of wonder: the creation of the idea of science fiction. Liverpool University Press.

Wetton, N. M., & McWhirter, J. (1998). Images and Curriculum Development in Health Education. In J. Prosser (Ed.), *Image-based Research, A Sourcebook for Qualitative Researchers* (pp. 263–283). London, UK: Routledge.

Whetten, D. A., & Cameron, K. S. (2016). *Developing management skills* (9th ed.). Harlow, UK: Pearson Education Limited.

White, A. R. (1990). *The Language of Imagination*. Oxford, UK: Basil Blackwell.

Whiten, A., & Suddendorf, T. (2008). Great Ape Cognition and the Evolutionary Roots of Human Imagination. In I. Roth (Ed.), *Imaginative Minds*. Oxford, UK: Oxford University Press.

Wikipedia. (2018). *Nachhaltigkeit*. Retrieved from https://de.wikipedia.org/wiki/Nachhaltigkeit

Wipawayangkool, K. (2009). Toward a General Model of Knowledge Creation in Virtual Teams. *Journal of Information & Knowledge Management*, *8*(1), 45–51. doi:10.1142/S0219649209002233

Wittgenstein, L. (1958). *Philosophical Investigations* (2nd ed.; G. E. M. Anscombe, Trans.). Basil Blackwell.

Wölfflin, H. (1948). *Kunstgeschichtliche Grundbegriffe. Das Problem der Stilentwicklung in der neueren Kunst* (9th ed.). München, Germany: Münchner Verlag.

Wopfner, G. (2012). Zwischen Kindheit und Jugend – ein sehender Blick auf Kinderzeichnungen. *Journal für Psychologie*, *20*(3), 1–28.

World Economic Forum & Asian Development Bank. (2017). *ASEAN 4.0: What does the Fourth Industrial Revolution mean for regional economic integration?* Retrieved from: http://www3.weforum.org/docs/WEF_2017_ASEAN%204IR.pdf

World Economic Forum. (2016). *The future of jobs: employment, skills and workforce strategy for the Fourth Industrial Revolution*. Cologny: WEF.

World Economic Forum. (2016). The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution. *Global Challenge Insight Report*. Retrieved from: http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf

World Economic Forum. (2019). *The future of jobs report: Employment, skills and workforce strategy for the Fourth Industrial Revolution*. Retrieved February 4, 2019 from http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf

World Wildlife Found (WWF). (2018). *Living Planet Report 2018: Aiming higher*. Retrieved from https://wwf.panda.org/knowledge_hub/all_publications/living_planet_report_2018/

Xerry, M. J. (2013). *Are committed employees more likely to exhibit innovative behavior: A social exchange perspective* (Doctoral Dissertation). Retrieved May 05, 2019 from https://epubs.scu.edu.au/cgi/viewcontent.cgi?article=1323&context=theses

Xiaogang, C., Xue, L., Clark, J. G., & Dietrich, G. B. (2013). Knowledge sharing in open source software project teams: A transactive memory system perspective. *International Journal of Information Management*, *33*(3), 553–563. doi:10.1016/j.ijinfomgt.2013.01.008

Xing, B., & Marwala, T. (2017). Implications of the Fourth Industrial Age for Higher Education. *Science and Technology*, *73*, 10–15.

Xiongfei, C., & Ahsan, A. (2018). Enhancing team creative performance through social media and transactive memory system. *International Journal of Information Management*, *39*, 69–79. doi:10.1016/j.ijinfomgt.2017.11.009

Yang, C., & Pan, J. (2015, September 11). Taiwanese work many hours of overtime: paper. *Taipei Times Online.* Retrieved April 20. 2019 from http://www.taipeitimes.com/News/taiwan/archives/2013/06/29/2003565940

Yates, J. K. (2016). Sustainability in engineering design and construction. Boca Raton, FL: CRC Press, an imprint of the Taylor & Francis Group.

Yoo, Y., & Kanawattanachai, P. (2001). Developments of transactive memory systems and collective mind in virtual teams. *The International Journal of Organizational Analysis*, *9*(2), 187–208. doi:10.1108/eb028933

York, R., & Rosa, E. (2003). Key Challenges to Ecological Modernization Theory. *Organization & Environment*, *16*(3), 273–288. doi:10.1177/1086026603256299

Zabelina, D. L., & Andrews-Hanna, J. R. (2016). Dynamic network interactions supporting internally-oriented cognition. *Current Opinion in Neurobiology*, *40*, 86–93. doi:10.1016/j.conb.2016.06.014 PMID:27420377

Zanni, A. (2015). *Cyber-physical systems and smart cities, IBM Big data and analytics.* Retrieved https://www.ibm.com/developerworks/library/ba-cyber-physical-systems-and-smart-cities-iot/

Zhang, J., & Patel, V. L. (2006). Distributed cognition, representation, and affordance. *Pragmatics & Cognition*, *14*(2), 333–341. doi:10.1075/pc.14.2.12zha

Zhang, L. Y., & Jin, Y. H. 2010. The Influence of Transactive Memory System on Team Effectiveness. *International Conference on Information Management, Innovation Management and Industrial Engineering (ICIII)*, 18-22. 10.1109/ICIII.2010.483

Zhang, Y., Fang, Y., Wei, K.-K., & Chen, H. (2010). Exploring the role of psychological safety in promoting the intention to continue sharing knowledge in virtual communities. *International Journal of Information Management*, *30*(5), 425–436. doi:10.1016/j.ijinfomgt.2010.02.003

About the Contributors

Ziska Fields is an Associate Professor at the University of Johannesburg, South Africa. She has 13 years' experience in the Financial Industry and 11 years' experience in Higher Education experience. Her qualifications include a BA (Communication Sciences), Diploma in Management Studies, MBA (Cum Laude) and PhD. She teaches various Management and Entrepreneurship courses at undergraduate and postgraduate levels. Her research focus area and passion is theoretical and applied creativity across various disciplines and contexts. She also has various other research areas, which include Entrepreneurship, Management, Innovation, Higher Education, Responsible Management Education, Human Resources, Future Studies and Information Technology. She edited four books titled "Incorporating Business Models and Strategies into Social Entrepreneurship", "Collective creativity for responsible and sustainable business practice", "Handbook of Research on Information and Cyber Security in the Fourth Industrial Revolution" and "Responsible, Sustainable, and Globally Aware Management in the Fourth Industrial Revolution". She has published various book chapters and papers and presented various conference papers. Professor Fields developed two theoretical models to measure creativity in South Africa, focusing on youth and tertiary education.

Julien Bucher is a research fellow and lecturer at the Chair of Innovation Research and Management of Technology at the Faculty of Economics and Business Administration of the Chemnitz University of Technology. His research focuses on social and technological innovation, especially in regard to visuality, imagination, creativity, sustainability, and frugality.

Anja Weller is the advisor for digitalization and media education at the Saxon State Ministry Of Education and Cultural Affairs, Germany. She studied media and communication studies at the University of Technology in Chemnitz. In her doctoral thesis she developed and applied the visual research methodology 'the creative interview'. Her research interests are visual sociology, learning, imagination, and media education.

* * *

Deonie Botha is the Associate Director responsible for Knowledge management at Deloitte Africa. She has managed the Knowledge management capabilities of various listed She has published widely on the topic of Knowledge management and the Future of Work. Dr Botha lectured in Knowledge management at the University of Pretoria (2001-2008). She is a Board member of the South African Society of Knowledge Management and have an extensive list of publications and presentations which include two books, more than twenty-one titles on Knowledge management and several study guides for local universities. Dr Botha holds a doctorate and masters degrees in Information Science and Information technology and is working towards a MSc in Mining Engineering.

Rajashree Chaurasia received her B.Tech. (I.T.) and M.Tech. (I.T.) degrees from Guru Gobind Singh Indraprastha University, Delhi, India, in 2009 and 2014, respectively. She is a gold medallist in both, B.Tech. as well as in M.Tech., and UGC NET qualified. She was with Infosys Technologies Ltd. from 2009 to 2011 and thereafter taught at Guru Tegh Bahadur Institute of Technology for a year. She is currently serving as a Lecturer (HOD/In-charge) in the Department of Computer Engineering, at Guru Nanak Dev Institute of Technology, Delhi (a Government of NCT of Delhi institution), since 2012. She holds a Group 'A' Gazetted post in the above institution. She is an active researcher in the fields of Computer Security, Computer Graphics and Computational Biology. She is a lifetime member of CEGR (Centre for Education, Growth and Research) as well as a member of ACM since 2018.

Rebecca Frenz is currently a Masters Student at Chemnitz University of Technology.

Anja Herrmann-Fankhänel is a research associate at the chair Innovation Research and Technology Management at Chemnitz University of Technology. Anja holds a Master's Degree in Management and Organization Studies. Her main research interest is the international Sharing Economy. From this starting point she investigates in related innovation, business models, and international differences and challenges as well as social entrepreneurship, sustainable development, and solidarity in economy. She lectures at Master's Level in e.g. consulting and innovation research. She was a lecturer for management, scientific writing and methods, and project management at Bachelor's level. Moreover, Anja is majorly involved in the project between her university and the University of KwaZulu-Natal that has the aim to jointly develop future managers to become more responsible and globally aware.

York Kautt, PhD in 2006, Habilitation Treatise in 2015. Main research: Sociology of visual communication and design, sociology of media and culture, food studies, methods of qualitative research.

Evi Kneisel has been working as a research assistant at the Chair of Personnel and Leadership at Chemnitz University of Technology since March 2016. From 2001 to 2006 she studied psychology at the Technical University of Chemnitz with a focus on economic and organizational psychology. Since graduating as a psychologist in 2006, she has been working as a research associate at the Chair of Economic, Organizational and Social Psychology of the TU Chemnitz and at the SRH University of Health Gera. In her doctorate to Dr. rer. pol. she addressed the impact of team reflections on shared mental models and team performance. Her current research focuses on high-performance teams, team cognitions, knowledge management and team learning, as well as trends in human resource management.

Julia Krause is a scientific assistant at the chair for Corporate Environmental Management and Sustainability at Chemnitz University of Technology. Prior to this appointment she owned the position of the Head of Technical Regulation with the internationally operating German engineering company. The theoretical knowledge is based upon her years-long teaching activities as a university lecturer at Chemnitz University of Technology. Krause holds a doctor degree in Economics (Chemnitz University of Technology/ Germany, 07/2015), an MBA in Production Management (CUT/ Germany, 11/2011), a diploma in social sciences and philology (VGPU/ Russia, 07/1999), a Bachelor of Arts degree (VGPU/ Russia, 07/1998). Additionally, she is an Auditor for Quality Management Systems, TÜV Süd, Germany. Furthermore, she attests a wide range of further qualifications in the fields of Explosion Protection, Engineering of hazardous installations, Compliance Management, Health and Environmental Safety, Technical Sales, Business Succession. She is a Nominated Expert for EU-Russia Industrialist Round Table, TF 8 in 3 Working Groups: “Conformity Assessment”, “On safety of machines and equipment”, “On safety equipment for working in hazardous environments”. She is the Author of the book “Regulation of Investment projects in Russia”, published by Springer (Germany, 2016) and some articles in professional journals.

Justine Walter holds a PhD in Comparative History and an MA in International Human Resources Management. Currently, she is concerned with economic and cultural implications of the digital transformation and emerging technologies. Her research interests include the past and future of labour, historical disasters and intercultural encounters along the Silk Roads.

Index

E

F

G

H

I

K

M

N

P

Q

R

S

T

V

W