Master Thesis

Challenges and potential solutions for the industrial workforce of the future

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Abstract

The thesis aims to identify future requirements to the manufacturing workforce in the automotive industry in year 2035 and beyond. Main focus lies within more developed countries such as e.g. the United States or European countries. As an outcome, potential training methods to prepare the future workforce for the identified challenges are evaluated.

Actual global megatrends and their implications for the future workforce are analyzed. Digitization and the demographic change are further investigated. The fourth industrial revolution, its enablers and industry impacts are discussed. Furthermore, changing characteristics and training needs of future workers due to demographic change and basics in didactics form the theoretical basement to create suitable training methods.

Supported by interviews with experts of Magna Powertrain and other successful companies within the global automotive and manufacturing industry, changes between actual and future situation related to the employees' tasks, skills needs and characteristics of successful training methods are evaluated.

The findings result in a framework for potential future training methods with respect to future needed skills and suitable didactical models. Implementation suggestions are given to derive company-specific employee development solutions.

Kurzfassung

Die vorliegende Arbeit beschäftigt sich mit zukünftigen Anforderungen an Arbeiter und Angestellte in der Automobilindustrie. Die Studie fokussiert hauptsächlich auf Nordamerika und Europa in einem Zeitfenster von 2035 und darüber hinaus. Das Ziel der Arbeit ist potentielle Trainingsmethoden für zukünftige Produktionsmitarbeiter zu evaluieren.

Aus einer Vielzahl von globalen Megatrends werden Digitalisierung und der demographische Wandel und deren Auswirkungen auf zukünftige Arbeitskräfte analysiert. Die in diesem Zusammenhang stehende vierte industrielle Revolution, die damit in Verbindung gebrachten Entwicklungen und dessen Auswirkungen auf die Arbeitswelt werden zunächst beleuchtet. Der in weiterer Folge diskutierte demographische Wandel, und die damit implizierten veränderten Bedürfnisse der zukünftigen Arbeitskräfte in Bezug auf Ausbildung und Beruf, bilden gemeinsam mit den erhöhten Wissensbedarf durch die vierte industrielle Revolution einen steigenden Bedarf an kontinuierlicher Weiterbildung. Didaktische Grundlagen und Konzepte zur beruflichen Weiterbildung werden zusätzlich diskutiert.

Unterstützt wird die Literaturrecherche durch Interviews mit Experten von Magna Powertrain und weiteren Führungskräften der Automobilindustrie, sowie generelle Produktionsspezialisten aus weiteren Industrien. Die Herkunft der Experten beschränkt sich auf europäische Experten (Österreich, Deutschland, Spanien) und amerikanische Experten (San Francisco Bay Area). In diesen Gesprächen werden Unterschiede zwischen aktuellen und zukünftig erwarteten Tätigkeiten und Fähigkeiten der Arbeitskräfte diskutiert, sowie Charakteristika potentiell erfolgreicher Trainingsmethoden besprochen.

Die evaluierten Trainingsmethoden werden als generisches Konzept für zukünftige Fortbildungen zur Reaktion auf die Auswirkungen der vierten industriellen Revolution und des demographischen Wandels zusammengefasst. Anschließend werden Handlungsempfehlungen zur Implementierung dieser Konzepte für Unternehmungen in der Automobilindustrie abgeleitet.

Acknowledgement

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1 Introduction

Technology is continuously improving customer's lives when it comes to mobility and connectivity. This has already progressed to an advanced status through the development of e.g. smart homes, smart vehicles, or smart phones and the high number of apps available in the market place.

In 2004, Frank Levy and Richard Murnane cited driving a vehicle in traffic as task not easily to substitute by computers. [1] Within a few years, the first cars are autonomously driving in traffic. Even if there are still situations self-driving cars are not able to handle, this scenario was never expected to turn into reality within these few years.[2] When the reigning chess world champion Garry Kasparov got defeated by IBM's computer Deep Blue in 1997, chess duels between computer and people became very one-sided. On the question about the strategy to beat a computer, the chess grandmaster Jan Hein Donner answered: *"I would bring a hammer."*[3]

The development of digital technologies[4] is predicted to continue exponentially into new areas such as manufacturing, logistics, energy transferability, etc. Furthermore, it is expected that emerging technologies are highly impacting organizational structure and operations, and thus will dramatically change the day-to-day routine of the workforce. Enhanced by the demographic change and aging population, there is potential exposure through the difficulties encountered in filling open positions and replacement needs for the skilled workforce of the future.

1.1 Initial situation

One of the biggest and most competitive industrial segments is the automotive industry, which requires major changes from cradle to grave:

[1] Cf. Levy & Murnane (2004), p. 48

[2] Cf. Brynjolfsson & McAfee (2014), pp. 18

[3] Cf. Brynjolfsson & McAfee (2014), p. 189

[4] In literature, this evolution is often referred to computerization and later digitalization or digitization. Distinctions between the different phrases are not clearly specified and thus this thesis refers to digitization as superordinate term.

process, product, and application due to a high number of global megatrends.[5] Cars are being designed more efficient and built faster, despite more variety. As a result the vehicle industry, including its supply base, has to react proactively to this evolution. Time-to-market will be increasingly important to stay competitive and to meet the needs of the customers. Suppliers will especially be affected by this evolution, as they have to be even faster than the OEM itself.

As manufacturing and design needs to become more efficient and effective, new production concepts and technologies need to be developed. The digital world is predicted to disrupt manufacturing technologies and business models, while population is decreasing and workforce is getting older.[6]

Therefore, a great deal of thought needs to be given on future workforce requirements and employee development methods for future manufacturing workforce.

1.2 Objectives

The object of this thesis is to identify possible courses of action to counteract a potential lack of adequate skilled workforces with respect to the specific requirements of a global automotive supplier. Main focus lies in more developed regions with focus on U.S. and European countries. Additional, examples of different regions and countries are researched to identify microeconomic differences.

In order to counteract a potential lack of adequate skilled labor, a framework to design individual training methods for industry is expected. This framework is required to consider implications on future tasks of shop-floor workforce, as well as implied changes in needed skills, abilities and knowledge due to the fourth industrial revolution and the demographic change.

[5] Cf. Schwab (2016), pp. 14

[6] The two megatrends (1) digitization and (2) the demographic change are two main challenges faced within this thesis as they are directly affecting the industrial workforce. Their impact on manufacturing workforce will be extensively discussed within chapter 2.

1.3 Approach

As a first step, literature research is conducted to gain basic knowledge about predictions related to digital production environment and the aging workforce. The focus lies on technological quantum leaps within the fourth industrial revolution and implied changes to an organization.

It is of highest interest to discover the impacts on manufacturing workforce. Shop-floor jobs of Magna Powertrain Plant Lannach get analyzed with respect to their tasks and the risk of getting substituted by computerized equipment based on a study of Frey & Osborne (2013). Literature research, and interview sessions with responsible personnel are conducted to gain necessary information. The generated knowledge describes actual tasks and skill level of shop-floor employees. This knowledge is used to identify main characteristics of future education and training needs.

Additionally, international experts of manufacturing and automotive industry are interviewed to suggest their ideas on future manufacturing work life. They are asked about future challenges for manufacturing industry, tasks performed by human labor, therefore needed skills and adequate training methods.

Finally, the outcome of literature research and experts interviews is discussed with experts of Magna Powertrains People Development and Training Team, defining a framework to design training methods based on individual companies' needs.

1.4 About Magna Powertrain

Magna Powertrain is a global automotive industry supplier with full capabilities in powertrain design, development, testing and manufacturing.[7] The company consists of more than 50 plants on a global presence, serving more than 70 customers worldwide. This thesis often refers to the Austrian Magna Powertrain Plant Lannach that combines engineering and

[7] Cf. http://www.magna.com/capabilities/powertrain-systems [21.03.2016]

manufacturing capabilities and represents the biggest European plant of Magna Powertrain, serving as European Head Office.[8]

The company's mission is to develop and supply mechanically or electronically controlled Powertrain and Electronic systems and components that enhance overall performance of the vehicle while improving fuel economy, enhancing vehicle safety and reducing weight. The following list shows the portfolio of Magna Powertrain within the different groups. [9]

Driveline Systems

- Actuators including System Control
- AWD/4x4 Disconnect Systems
- Coupling Systems
- Axle Drive Systems
- Power Take-Off Units
- Rear Drive Modules
- Transfer Cases

Electronics

- Near Field Applications/Multicamera Systems
- Far Field Applications/Data Processing
- Sensor Fusion Capabilities
- Control Units for different Applications
- Driver Assistance Systems
- Electronics Manufacturing Services

Engineering Services (external and internal)

- Vehicle & Powertrain Engineering
- Simulation & Technical Application Software
- Prototyping and Production
- Testing Services

Fluid Pressure & Controls

- Engine Oil, Vacuum and Water Pumps
- Tandem Pumps

[8] Cf. Magna Powertrain (2016), pp. 5

[9] Cf. Magna Powertrain (2016), pp. 9

- Transmission Oil Pumps
- e-Pumps (Coolant, Oil, Purge, Vacuum)
- Integrated Engine Front Cover Modules
- Thermal Management Modules
- Electronic Cooling Fans
- High Pressure Hydraulic Pumps

Getrag

- Manual Transmissions
- Dual-Clutch Transmissions
- Hybrid Transmissions
- Transmissions for electrical drivetrains

Metal-Forming Solutions

- Accessory Drives
- Clutch Hubs & Housings
- Flexplates
- Geared Products
- Oil Pan Modules
- Planetary Carriers
- Transmission Clutch
- Modules

New and Advanced Products

- e-Mobility Systems
- Powertrain efficiency improvements

2 Literature review

Within the next chapters, literature about actual and future developments in manufacturing due to global megatrends is reviewed. Because of the direct impact on the future industrial workforce, this thesis focuses on digitization and the demographic change. This includes actual trends in technological developments and their related outreach on employment. Potential effects of the demographic change related to the future workforce is covered within chapter 2.2. Finally, theoretical background of education methods and examples of innovative education methods are described in chapter 2.3.

2.1 Digitization in manufacturing

The following sub-chapter aims to analyze the ongoing trend digitization and its impact on manufacturing industry. At first, its way into automotive industry and further the manufacturing environment is discussed. A brief overview of manufacturing industries' history is provided in a next step. Finally, key enablers of the fourth industrial revolution and their implications on future workforce are discussed.

2.1.1 From consumer markets to industry

It is crucial to understand digitization is far more than a trend of digital services or connected devices in consumer markets. Smart products, apps and social networks improve customers' life and thus often cause a societal transformation. This leads to rising exponentially adoption rates of connected devices and digital services at increasing speed with every new technology.[10] A study of Gartner (2014) predicts a typical household by 2022 could contain more than 500 smart devices[11], compared to only ten devices in 2012.[12]

In 2011, digitization measurably boosted productivity and employment globally, adding USD 193 billion to the world economy and providing 6 million

[10] Cf. Lässig (2015), p. 6

[11] Cf. http://www.gartner.com/newsroom/id/2839717 [26.01.2016]

[12] Cf. OECD (2013), p. 4

jobs worldwide. It is predicted to further accelerate as nations move forward with more advanced stages of digitization.[13]

As industry recognizes the power of digital technologies, there is high exposure that digitization impacts manufacturing technologies and business models dramatically.[14]

2.1.2 How digitization challenges the automotive industry

The automotive industry is an essential engine of global economic growth.[15] After the economic crisis in 2008/2009, the global automotive industry has clearly recovered, as profits show. Back in the last pre-crisis year 2007, automotive industry profits reached about EUR 41 billion. In 2012, profits have exceeded this number, reaching EUR 54 billion. Prognoses for 2020 foresee an increase in global profit of about EUR 25 billion to a total value of EUR 79 billion.[16]

Within the last couple of years, also the automotive business started to get digitized. This trend clearly starts where customers are involved e.g. within the purchasing process. A study of Arthur D. Little (2014) shows, 70% of customers are researching cars mainly online and between 30-65% are willing to purchase it online.[17] In 2014, Volvo introduced their completely new XC90 crossover model. A limited run of only 1.927 pieces was available for sale via digital commerce only. Surprisingly, all of the 1.927 cars were reserved one hour after start and sold within 47 hours.[18]

Digitization is also affecting the product itself. The number of cars connected to the internet is predicted to continuously grow about 30% p.a. for the next couple of years, according to McKinsey & Company (2013).[19] Customers claim more sophisticated infotainment systems at a low price as a serious

[13] Cf. Sabbagh, et al. (2013), p. 35

[14] Cf. Bechtold & Lauenstein (2014), p. 7

[15] Cf. Corwin, et al. (2015), p. 3

[16] Cf. Mohr, et al. (2013), p. 7

[17] Cf. Arena, et al. (2014), pp. 4

[18] Cf. Volvo Car Group (2014), pp. 1

[19] Cf. Mohr, et al. (2013), p. 14

need. They are expecting more high-end features to be standard.[20] This development has already processed to an advanced status, as more and more customers are willing to change brands to get a better connectivity, or even partial or full autonomous vehicles.[21]

Different principles of connectivity are predicted to become implemented in future cars. By integrating electronic control modules, sensors, as well as innovative communication technologies into cars, communication between vehicles (vehicle-to-vehicle or V2V), vehicles and infrastructure (vehicle-to-infrastructure or V2I) and other smart devices (vehicle-to-everything or V2X) will be enabled.[22] These technological quantum leaps are already developed and ready for use in real life conditions is shown by various examples of autonomous driving research activities. Best known is the example of Google's self-driving car, which was already driving more than one thousand miles on public road in autonomous condition.[23] Autonomous cars already arouse the interest of many customers, as a study of McKinsey & Company (2015) shows that 50% of U.S. and German customers claim high need for legalization of autonomous cars. In China, even 90% car customers want this legalization.[24]

2.1.3 Manufacturing under rapid change

People are used to the speed of consumer electronics, so they expect the same for cars. OEMs already face a product velocity gap in terms of lifecycles and system updates. The lifecycle of a typical car has went down to five to seven years, new vehicle launches even in three to four years. Against that, operating systems get updated within months down to a few weeks to react on bugs, vulnerabilities or introduce new features based on customer wishes. Thus, speed within product development and manufacturing is getting increasingly important.[25]

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[20] Cf. Viereckl, et al. (2015), pp. 8

[21] Cf. Kaas, et al. (2015), p. 1

[22] Cf. Corwin, et al. (2015), p. 2; Hong, Wallace, & Krueger (2014), p. 9

[23] Cf. Google Self-Driving Car Project (2015), p. 1

[24] Cf. Kaas, et al. (2015), p. 5

[25] Cf. Hirsh, et al. (2015), pp. 2 ; Kaas, et al. (2015), p. 4

Additionally, also market requirements and customer demand is expected to change within shorter cycles. These cycles will shrink from high weekly changes or even high daily changes in some industries. Classic production industries like Germany will be very strongly affected. Because these changes are not easy to plan, companies have to be agile and flexible enough to thrive in a competitive environment of continuous and unanticipated change.[26]

2.1.4 The fourth industrial revolution and it's key enablers

Historically, in the world of manufacturing, the continuous development of disruptive technologies caused what we later referred to industrial revolutions. Starting with the first water and steam power driven mechanical production equipment in late 18th century, the first industrial revolution has progressed. The second industrial revolution was shaped by the use of electrical energy and the division of labor. The first mass production systems have been introduced within this era. The third industrial revolution has started in the late 20th century. By using electronics and Information Technologies (IT), production systems have been further automated and enabled mass customization strategies.[27]

The last centuries where shaped by increasing offshoring of manufacturing activities from western to eastern countries. This development has led to a decrease in manufacturing jobs and thus also manufacturing know-how got lost over time.[28] Over time, the western countries have faced tough competition from emerging countries. This has progressed into increasing service orientation and deindustrialization within high-wage countries.[29]

Today, industry is moving forward to the fourth industrial revolution, which is predicted to be a fusion of physical and virtual world. Industry 4.0, Industrial Internet or Advanced Manufacturing are paradigms of different regions to describe this development and its related outcome.[30] It is also described by

[26] Cf. Bechtold, et al. (2014), p. 27; Spath, et al. (2012), pp. 68

[27] Cf. Bauernhansl (2014), pp. 5; Spath, et al. (2012), p. 23

[28] Cf. Ebenstein, et al. (2014), pp. 581; Ramsauer (2013), p. 1

[29] Cf. Blanchet, et al. (2014), p. 3

[30] Cf. Bechtold & Lauenstein (2014), p. 4

digitization of manufacturing equipment.[31] Machines are predicted to connect and interact with one another – parts, other machines and human - creating intelligent networks of autonomously acting production systems to ensure highly efficient and agile manufacturing processes.[32]

Figure 1 provides an overview of the four industrial revolutions including the most important technological developments. It additionally illustrates the increasing level of complexity in every single phase.

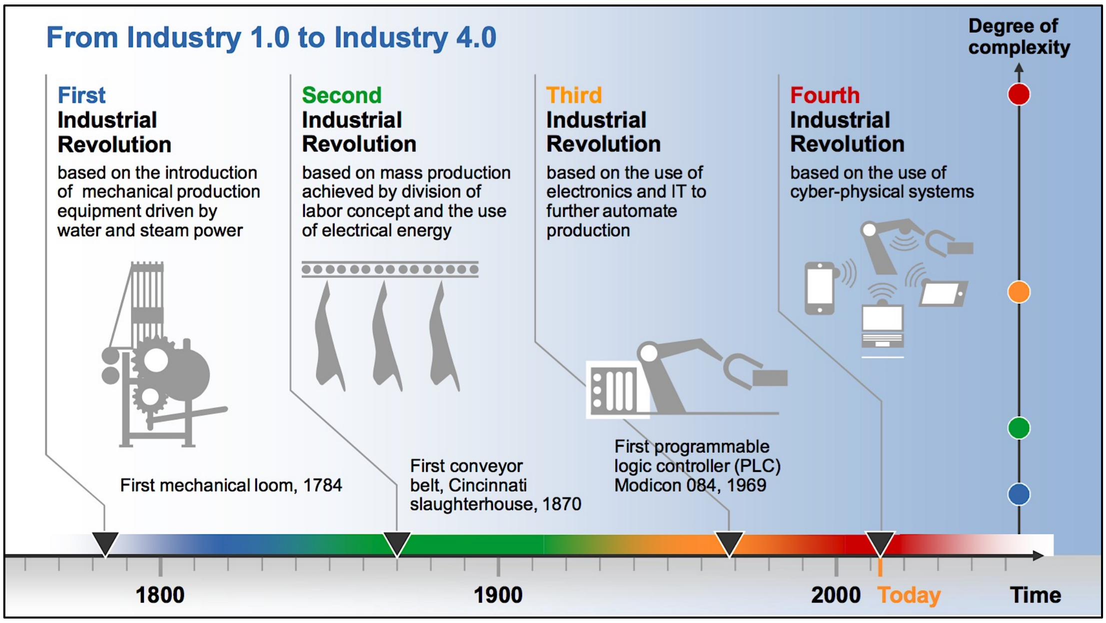

Figure 1: The four industrial revolutions[33]

In future manufacturing environment, products are predicted to contain all production relevant information on their selves. This enables self-organization of integrated production installations along the entire value chain. Decentralized Cyber-Physical Systems (CPS) will interact via embedded internet-based technologies and thus support flexible decision-making on production process based on current situation and events.[34] These smart products will be precisely identified and localized within the

[31] Cf. Bechtold & Lauenstein (2014), p. 4; Wang, et al. (2015), pp. 1

[32] Cf. Bechtold & Lauenstein (2014), p. 4; Geisberger & Broy (2012), p. 20; Rüßmann, et al. (2015), p. 2; Wang, et al. (2015), pp. 1

[33] Russwurm (2013), p. 4

[34] Cf. Russwurm (2013), p. 5

smart factories and all occurring information will be stored and transported. This will increase efficiency, flexibility, robustness and quality levels within all engineering, planning, production, operations and logistic processes. Predictive maintenance and remote management will vastly improve operational efficiency.[35] Individual customer requests will be processed in an economic order, as production lines will be able to react on short-handed changes in demand, breakdowns and other unpredictable disturbances.[36]

The following sub-chapters aim to identify actual research activities on the fourth industrial revolution and highlight enabling technologies.

International research activities on the fourth industrial revolution

A high number of cooperation and initiatives have been established around the world to research the impact of the fourth industrial revolution and develop solutions for successful realization.

In Germany, the “Plattform Industrie 4.0” was developed with the target to define realization strategies and first guidelines for industry. This initiative is driven by the German Ministries „Bundesministerium für Wirtschaft und Energie“ (BMWi), „Bundesministerium für Bildung und Forschung“ (BMBF) and representatives of industry, science and unions.[37] Regional delegations have been established, also in surrounding countries such as the Austrian partnership of “Verein Industrie 4.0 Österreich - die Plattform für intelligente Produktion”[38]

In 2013, the Advanced Manufacturing Partnership “2.0” Steering Committee was launched by President Barack Obama. It aims to maintain the competitiveness of American manufacturing industry, to create high-quality

[35] Cf. Promotorengruppe Kommunikation der Forschungsunion Wirtschaft – Wissenschaft (2013), pp. 18

[36] Cf. Ramsauer (2013), p. 8.

[37] Cf. Bundesministerium für Wirtschaft und Energie (2015), p. 8

[38] Cf. http://www.feei.at/pressemeldungen/2015/06/startschuss-fuer-plattform-industrie-40-oesterreich [29.01.2016]

manufacturing jobs and uphold U.S. leadership role in technology development.[39]

Also China recognized the high potential lying in emerging technologies. They announced to implement the "Internet Plus" action plan to integrate digital technologies with modern manufacturing.[40]

On a global range, the Industrial Internet Consortium was founded to bring together a high number of large and small enterprises, entrepreneurs, academics and government organizations. It aims to drive innovation by creating new industry use cases, and to define global standards for internet and industrial systems. Initiators of the Industrial Internet Consortium are leading Information and Communication Technology (ICT) giants e.g. AT&T, Cisco and IBM.[41]

The big interest in the term Industry 4.0 (or in Germany "Industrie 4.0") has recently grown extensively, based on the high number of papers published or the growing number of search engine queries (see Figure 2).

[39] Cf. https://www.whitehouse.gov/the-press-office/2013/09/26/president-obama-launches-advanced-manufacturing-partnership-steering-com [25.01.2016]

[40] Cf. Keqiang (2015), p. 27

[41] Cf. http://www.iiconsortium.org/ [02.02.2016]

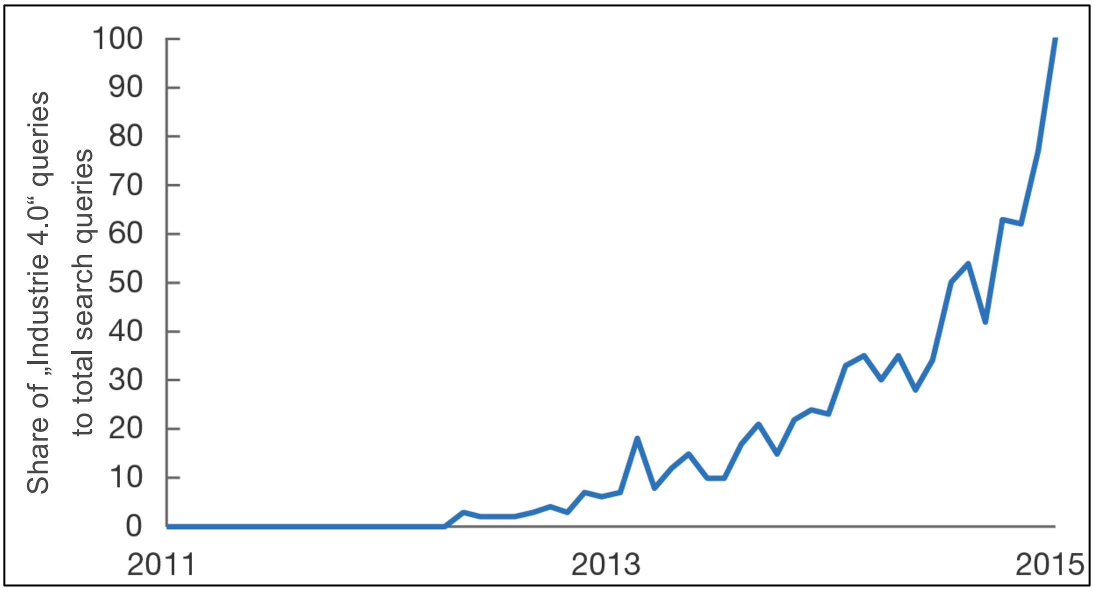

Figure 2: Google Trend graph for "Industrie 4.0" in Germany[42]

Technologies enabling of fourth industrial revolution

To realize the concept of Industry 4.0, several emerging technologies are referred as key enablers. To ensure the enhanced interconnection within production systems, emerging technologies are expected to follow the design of CPS and are connected to the (Industrial) Internet of Things.

CPS are systems that connect the physical and virtual world. They can be described as embedded systems, equipped with a high number of sensors to immediately obtain data from the physical world, power electronics and algorithms that process the real life and virtual data, and actuators to operate in the real world. These can be machines, tools, or even parts.[43]

Due to the extended availability of the internet and the fast developments in ICT, it is possible to connect CPS between products, machines, production lines, production plants and global networks. The communication channels enabling this network between machines, parts, products, etc. is described by the Internet of Things. Communication channels between processes, information, etc. are referred as the Internet of Services, connections over a

[42] Behrendt, et al. (2016), p. 1

[43] Cf. Geisberger & Broy (2012), p. 22; Majstorovic, et al. (2015), p. 10

broad network of human is referred as the Internet of Human. To unlock the full potential of communication, the three concepts get combined to establish a new dimension of virtual connection, which is referred as the Internet of Everything.[44] The industrial application of these concepts is called Industrial Internet.[45] It handles real time data accessing and processing.[46] Thus, the resulting global data availability vastly improves operational efficiency.[47]

Several technologies are handled as key enablers of the fourth industrial revolution. To understand the consequences they imply to future manufacturing workforce, it is important to understand what they are about.

Advanced robotics and artificial intelligence

A new era of smart robotics is one of the key factors affecting employees in manufacturing and part of the fourth industrial revolution. They are capable of performing physically exhausting, precise and repetitive tasks with constantly high quality 24/7, backed by decreasing hardware and increasing labor costs. Additionally, robots are becoming smaller, more energy efficient. Also more flexibility is given due to faster CPUs and easier application programming.[48] Therefore, adoption of industrial robots is predicted to grow within 8-12% annually within the next ten years.[49] A Boston Consulting Group study (2015) identifies at least 85% of tasks in the industry groups electronic/electrical equipment and components, transportation equipment and machinery are automatable and about 40-45% of the production tasks will be performed by robots.[50]

As artificial intelligence (AI) and creativity is further developed, non-routine tasks are predicted to become feasible by self-learning robots. The development of AI technologies has already started a long time ago. In 1997,

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[44] Cf. Sihn (2015), p. 18; World Economic Forum (2015), p. 3

[45] Cf. World Economic Forum (2015), p. 34

[46] Cf. Majstorovic, et al. (2015), p. 9ff

[47] Cf. World Economic Forum (2015), p. 3

[48] Cf. Ford (2015), pp. 1; Miremadi, et al. (2015), pp. 2; Sander & Wolfgang (2014), p. 2

[49] Cf. IFR (2015), pp. 13; Sander & Wolfgang (2014), p. 2; Tilley (2015), p. 2

[50] Cf. Sirkin, Zinser, & Rose (2015), p. 14

the world chess champion Garry Kimovich Kasparov was defeated by IBM's supercomputer Deep Blue in a six-game match. [51] Fourteen years later, the supercomputer Watson, which was developed by IBM, was able to defeat the two best human players of the quiz-show "Jeopardy!". The robot got feed with about 200 million pages of information (which has included dictionaries, reference books, works of literature, newspaper archives, and web pages including quite every content of Wikipedia) and a lot of very sophisticated algorithms.[52] Gil Weinberg, a professor for music technology at Georgia Tech, is convinced robots are able to compose music based on what they know and hear. According to his research, well-programmed algorithms can enable robots understand what people want listen to and how to combine the notes.[53] In 2012, the London Symphony Orchestra already played the first computer written composition.[54]

A study of MIT has researched how cooperation between human labor and supercomputers could look like and therefore tested teams of computers and human to perform certain tasks. It showed that robots allocating tasks to human is not just the most productive, but also the most satisfying condition to human labor. This includes scheduling, coordination and delegation of tasks based on human-generated algorithm.[55]

Advanced analytics and big data

Due to the use of digital equipment and the many smart products on the market, the level of data produced in manufacturing will virtually explode.[56] Advanced analytic tools and big data are expected to enable decoding complex manufacturing processes by identifying initial patterns, data correlation and inter-linkages within a network of machines, tools, material, etc.[57] Previously unsolvable and unforeseen problems will be resolved and

[51] Cf. Brynjolfsson & McAfee (2014), p. 50; Ford (2015), p. 97

[52] Cf. Baker (2011), pp. 78; Brynjolfsson & McAfee (2014), pp. 24;

[53] Cf. http://tedxtalks.ted.com/video/TEDxGeorgiaTech-Gil-Weinberg-To [02.02.2016]

[54] Cf. Ford (2015), p. 111

[55] Cf. Gombolay, et al. (2014), p. 293

[56] Cf. Bechtold, et al. (2014), p. 20

[57] Cf. Auschitzky, Hammer, & Rajagopaul (2014), pp. 2

real time decision making will be supported. Thus, it supports improvement efforts in areas such as Monte Carlo simulation, production and distribution planning, capacity planning, process parameter optimization as well as demand and pricing optimization.[58]

Additive manufacturing

Currently, additive manufacturing methods are mainly used for rapid prototyping. For a small number of applications e.g. dental or design objects, these technologies have already achieved manufacturing readiness. The potential of additive manufacturing is rated extremely high due to expected cost reductions and increasing productivity.[59] Especially 3D printing technologies in combination with 3D scanning are often referred as disrupting technologies. [60]

The benefit of these technologies lies in the diversity of producible goods. It is possible to produce highly customized parts at unprecedented shapes with marginally rising costs with the level of complexity. Production steps get eliminated as well as costly and time-consuming tooling.[61] High potentials are also seen in the use of new materials and materials mixes, increasing performance and quality. In the automotive industry, actually mainly luxury cars have built in printed parts. In future, drastic reduction of design-to-final time and better the local customer service in aftermarket and maintenance is expected.[62] As an example, the company Local Motors already uses 3D Printing technology to produce complete cars.[63]

Community platforms

New forms of collaboration, coordination and communication will evolve due to the use of community platforms. Interaction between employees and

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[58] Cf. Dhawan, Singh, & Tuteja (2014), p. 3

[59] Cf. Roland Berger Consultants (2013), pp. 5

[60] Cf. Gupta & Kumar (2013), pp. 225

[61] Cf. Roland Berger Consultants (2013), p. 18

[62] Cf. Giffi, Gangula, & Illinda (2014), pp. 15

[63] Cf. https://localmotors.com/3d-printed-car/ [04.02.2016]

customers are expected to become more dynamic and content-rich. Therefore, the human-to-human aspect of global industrial networks will be facilitated and enhanced. Using social media in manufacturing can support on demand manufacturing, scheduling employee work time of and provides wealth data about customers.[64] Employees change the way of gathering and analyzing data, of processing innovation and work more efficiently due to the use of these platforms in both private and business life. Within two days, interaction within social networks produces more data than the total population produced till 2003 without these communication channels. Making use of this data in real-time can unlock tremendous potentials in identifying correlations and thus making planning and operations more transparent and comprehensible.[65]

Cyber and proper security

Due to the increasing connectivity and use of standardized communication protocols, industrial systems and manufacturing lines are at higher risk of getting unauthorized accessed. Thus, the need for secure and reliable communications as well as sophisticated identity and access management tools is increasing.[66] In automotive business, a hacked product can easily become a safety hazard for the occupants, and road users around the vehicle. Additionally, the number of opportunities for cyber-attacks increases because of the continuously increasing number of digital services provided.[67]

Mobile technologies and augmented reality as Human-Machine interfaces

Using mobile technologies in a digitized network of manufacturing systems enables the user to request and process information of processes, equipment and product locally during production processes. They assist workers to detect errors earlier and minimize reaction time due to decentralized decision making opportunities. Therefore, user-friendly interfaces and visualization is needed. These technologies will also affect indirect production related

[64] Cf. Bechtold, et al. (2014), p. 22

[65] Cf. Baum (2013), p. 41

[66] Cf. Rüßmann, et al. (2015), p. 6

[67] Cf. Automotive World Ltd. (2015), p. 4

divisions (e.g. logistics) to guarantee sustainable information flow over the entire network.[68]

Cloud computing

Technologies in cloud computing are designed to provide on-demand computing services with high reliability, scalability and availability in distribution networks.[69] They refer to applications, platforms and infrastructure solutions, used as services to public or private networks on a pay-per-use basis.[70] Due to the use of cloud based monitoring and control processes and increasing performance of these services, reaction times of just several milliseconds, can be achieved.[71]

2.1.5 Digitization and it's integration into industry

History reviews that stubborn implementation of new technologies does not necessarily improve productivity. When first factories got electrified, the layout and organization followed the same design as in times of steam engines and thus didn't considerable improve their output. Three decades later factory layouts began to change from using single massive energy sources to the use of individually electrified machines and thus boosted productivity. The same *"Productivity Paradox"* evolved within the era of digitization. As an example, the invention of the World Wide Web initially didn't benefit the broad mass, but years later entrepreneurs found ways to use the web to reinvent publishing and retailing.[72]

Figure 3 visualizes the "Productivity Paradox" by overlapping the labor productivity growth graphs of both eras. The black graph refers to the electrification era from 1890-1940, the blue graph to the IT era (1970-2012) in U.S.

[68] Cf. Rüßmann, et al. (2015), p. 7; Kollatsch, et al. (2014), p. 246

[69] Cf. Xu (2012), p. 1

[70] Cf. Bechtold, et al. (2014), p. 20

[71] Cf. Rüßmann, et al. (2015), p. 6

[72] Cf. Brynjolfsson & McAfee (2014), pp. 100

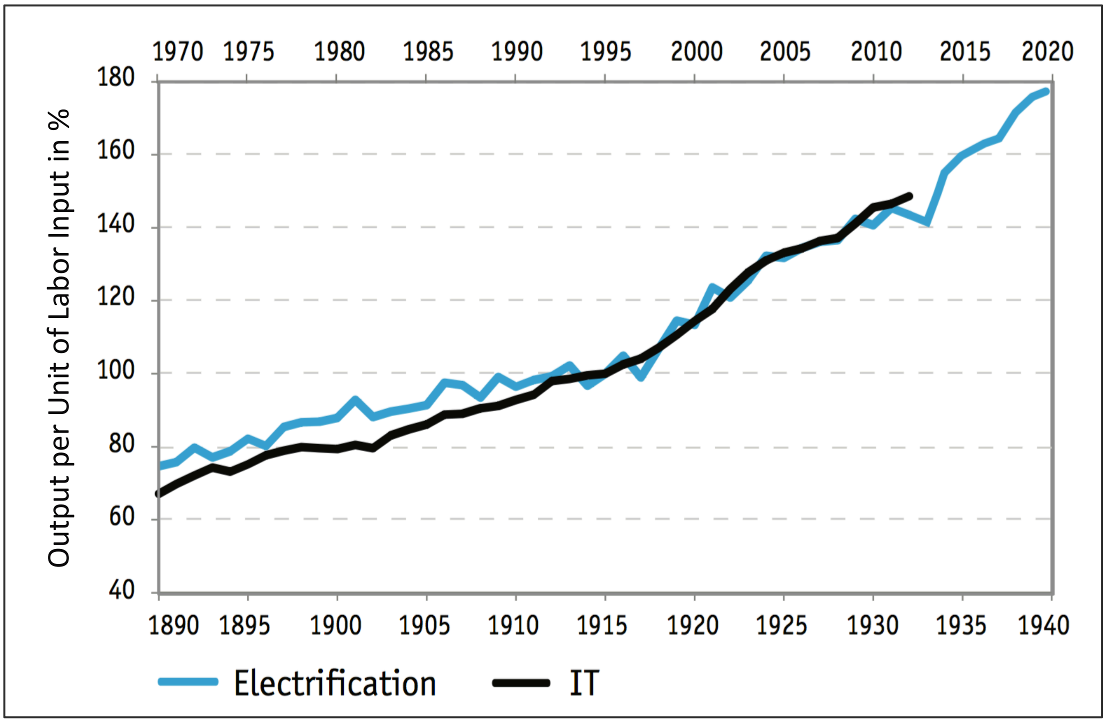

Figure 3: Labor Productivity in two eras[73]

The next sub-chapters deal with the integration of the prior discussed technologies and concepts into existing companies and their implications on organizational structure and labor.

Integration of emerging technologies

To gain the full potential of the fourth industrial revolution, integration must be handled in all eras over the entire product lifecycle and entire value chain. Literature distinguishes between the three integration scenarios horizontal, vertical and lifecycle integration.

Horizontal integration refers to the interconnectivity of all IT systems within all process steps. Material, energy and information flow is guaranteed within all departments of an organization, but also within many related companies to form efficient ecosystems. New value networks and business models can evolve of horizontal integration.[74]

[73] Syverson (2013), p. 38

[74] Cf. Promotorengruppe Kommunikation der Forschungsunion Wirtschaft – Wissenschaft (2013), p. 24; Wang, et al. (2015), p. 2

Against that, vertical integration describes the interconnectivity between hierarchical levels, including several physical and informational levels, from sensor and actuator level to corporate level. This means data has to be transferred and processed throughout all the levels right up to the Enterprise Resource Planning (ERP) system.[75]

Lifecycle integration refers to the integration of IT systems over the complete product lifecycle. Through the integration of the entire set of activities, starting with customer requirements expression, product design production planning control and engineering till service maintenance and recycling, a continuous and consistent model evolves. This model can be reused by every stage and dependencies within the stages can be foreseen and proactively maintained.[76]

Interoperable systems of all CPS and human within a plant, organization or even industry networks are predicted to evolve.[77] Virtual copies of the plants, its inventory and processes will be created, enabling real-time planning, monitoring, controlling and intervening if necessary. Disturbances can be identified immediately, simulation of processes can be processed in real-time with real data and thus errors can be handled within shortest time.[78] Due to data gathering within every single step of the entire system including product, tools, machines or processes, enhanced quality and traceability is ensured.[79]

Consequences on organizational structure

In general, mainly polarized organizations evolved within the last decades. This means medium-skills, medium-wage jobs[80] lose against low-skills, low-wage and high-skills, high-wage jobs.[81] Especially more developed regions

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75 Cf. Promotorengruppe Kommunikation der Forschungsunion Wirtschaft – Wissenschaft (2013), p. 24; Wang, et al. (2015), p. 2

76 Cf. Wang, et al. (2015), p. 2

77 Cf. Hermann, Pentek, & Otto (2015), pp. 11

78 Cf. Gorecky (2014), p. 535

79 Cf. Schlick, et al. (2014), p. 75

80 Medium-skilled worker imply white-collar worker such as clerical, administrative and sales occupations, as well as blue-collar worker e.g. production, craft and operations occupations.

81 Cf. Autor D. (2010), p. 12

e.g. U.S. and Europe are concerned.[82] Through this development and the increasing offshoring activities within the last decades[83], western manufacturing industry (especially in U.S.) is now facing highest shortage of a skilled production workforce e.g. machinists, operators, craft workers, distributors, technicians.[84]

As an outcome, labor intense jobs in developed countries have been reduced during last years and unemployment mainly affects youth in low skilled jobs.[85] According to Prof. Bauernhansl of the University of Stuttgart, there will be no chance for low-skilled jobs in future anymore.[86]

Organizational structures are expected to be further adopted e.g. using flat hierarchies and increasing decision making power to form agile manufacturing organizations. Furthermore, decentralized, modular, flexible and boundless operating models are highly required.[87] Supported by interoperable and virtualized networks, emerging technologies and intelligent CPS, decentralized decision making will be highly supported and centralized planning and controlling approaches will become obsolete.[88]

Thus, the German economist Hirsch-Kreinsen believes swarm organization will establish, representing self-organizing networks of highly skilled employees, as illustrated in Figure 4.[89]

[82] Cf. Autor & Dorn (2013), p. 1553; Goos, Manning, & Salomons (2009), p. 60

[83] As discussed in chapter 2.1.4.

[84] Cf. Morrison, et al. (2011), p. 4

[85] Cf. Dobbs, et al. (2012), pp. 23

[86] Cf. Spath, et al. (2012), p. 125

[87] Cf. Bechtold, et al. (2014), pp. 27

[88] Cf. Hermann, Pentek, & Otto (2015), pp. 11

[89] Cf. Hirsch-Kreinsen (2015), p. 95

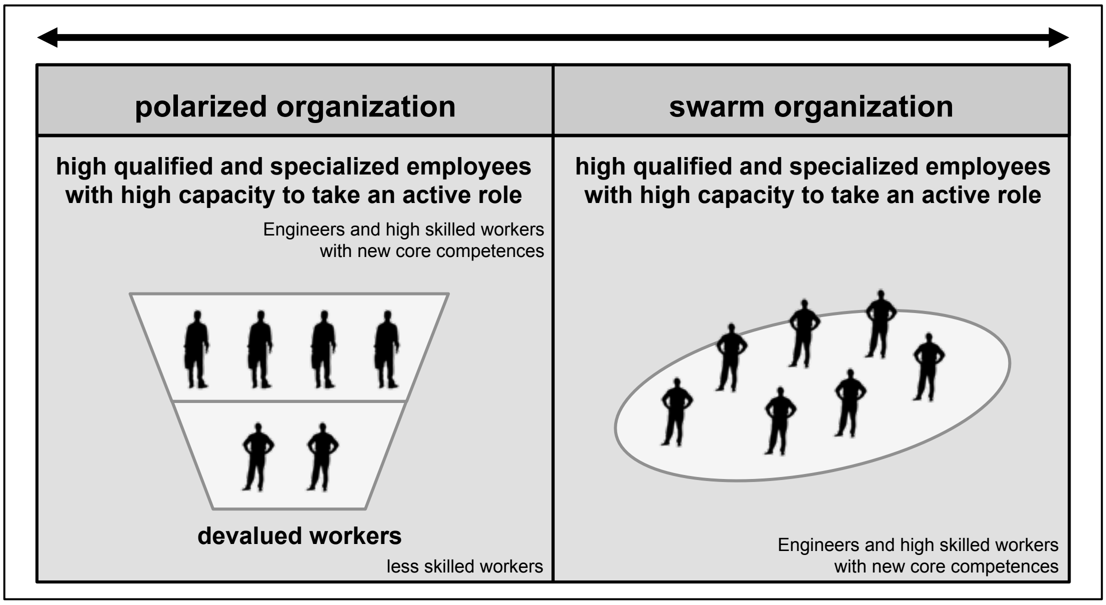

Figure 4: Polarized vs. swarm organization[90]

2.1.6 Changes in job structure due to digitization

Digital technologies often create the impression that human labor is being completely replaced by machines. Even experts wonder if any human skills and abilities will be valued as technology continues to improve. This generates fear and creates resistance against new technologies.[91]

Within past decades, if not centuries, almost every economy has been substituting capital for human labor by using technologies. We know these phenomena already from agriculture, when automatic threshing machines replaced 30 percent of labor force in the middle of the nineteenth century, and the industrial revolutions within the twentieth century.[92]

After the example of Garry Kasparov losing a chess game against a computer, it seemed human were not able to beat chess computers anymore. In a freestyle chess tournament initiated by Kasparov this assumption changed. Within these kind of events, teams are built of any combination between human and computer, of chess grandmasters and amateurs, of supercomputers and weak laptops. Surprisingly, the winning

[90] Illustration based on Hirsch-Kreinsen (2015), pp. 94

[91] Cf. BMWi (2015), p. 28; Brynjolfsson & McAfee (2014), p. 188

[92] Cf. Brynjolfsson & McAfee (2014), p. 143

team was made up of amateur chess players and a state-of-the-art PC. What made them win was perfect human strategic guidance with tactical acuity of a computer. They manipulated and coached their computers to look very close into positions and effectively counteracted the superior chess grandmasters and higher computational power.[93]

The next sub-chapters discuss the impact of digitization on human labor, with special focus on tasks and work regulations.

Socioeconomic implications of digitization

Despite the technological changes in production, the labor share of overall GDP has been surprisingly stable. Labor wages and living standards have grown roughly in line with dramatic increases in productivity. Within the past decade, the division between the shares of income between labor and physical capital tends to end (see Figure 5).[94]

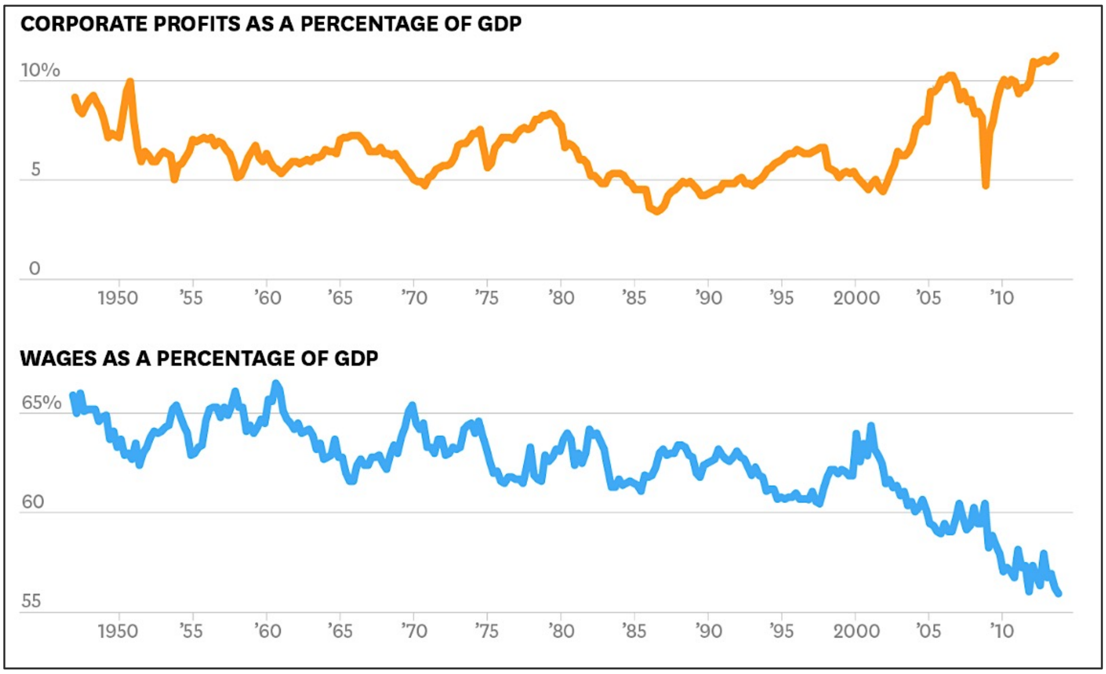

Figure 5: Wage share of GDP vs. corporate profit share of GDP[95]

[93] Cf. Kasparov (2010), pp. 5

[94] Cf. Brynjolfsson & McAfee (2014), pp. 143

[95] Cf. Bernstein & Raman (2015), p. 7

Due to the emerging technologies of the information age, the global labor share has significantly declined. As a consequence, fewer people are working and their wages have declined dramatically. A clear gap between productivity and labor compensation has emerged, especially dramatic from 2000 to 2009 (see Figure 6).[96]

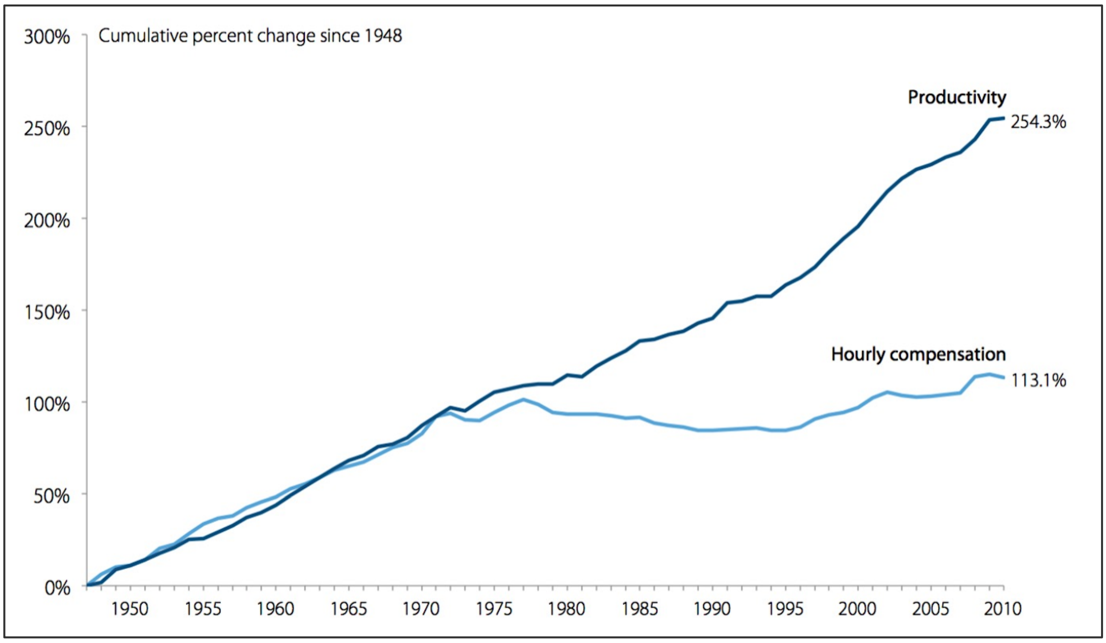

Figure 6: Growth of real hourly compensation for production/nonsupervisory workers and productivity, 1948-2011[97]

What these kinds of statistic are not able to handle are products and services offered for zero price e.g. online services like *Google* or *Wikipedia*. *Wikipedia* offers about fifty times as much information as the famous *Encyclopaedia Britannica*, and is available for free, at any time needed. By using online search machines like *Google*, enormous time saving is achievable. Because these services are available for free, they add value to the economy, but not to the GDP.[98]

On the other hand side, labor costs in western economies have risen five-fold since the 1970s. In China, manufacturing wages have risen five-fold only

[96] Cf. Brynjolfsson & McAfee (2014), pp. 144; Ford (2015), p. 36

[97] Mishel (2012), p. 2

[98] Cf. Brynjolfsson & McAfee (2014), pp. 111

since 2008, which is not expected to ease significantly in the foreseeable future. Additionally, as technology has developed further, technology costs have fallen dramatically. Figure 7 shows the development of labor costs compared with robot prices.[99]

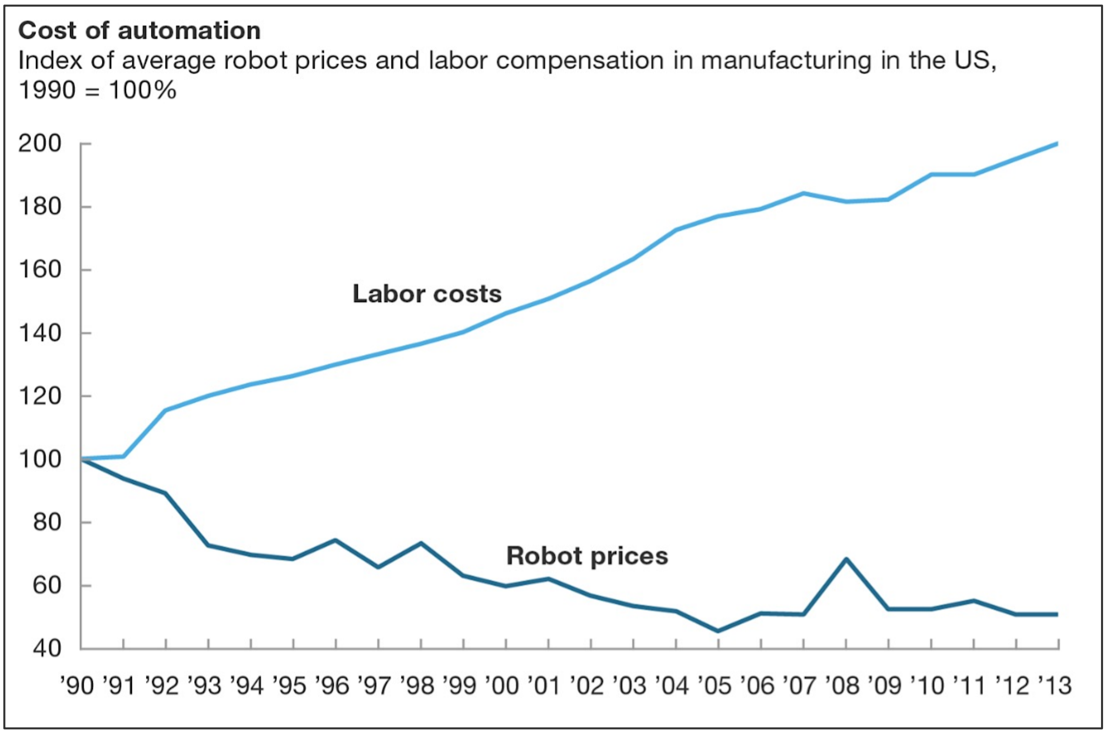

Figure 7: The sinking cost of automation and increasing labor costs have made the case for automation more viable over time[100]

These developments often create the anxiety that the number of available jobs shrinks down to zero and human labor is being entirely replaced by machines. But technologies also complement human performed tasks in carrying out tasks skilled labor couldn't do more effectively without new technology.[101] Also experts believe that in future, manufacturing work will still rely on the power of human labor. Dr. Klaus Mittelbach, CEO of ZVEI, predicts: *"The factory of the future will as deserted as today's offices are paperless"*[102]

[99] Cf. Tilley (2015), pp. 1

[100] Tilley (2015), p. 3

[101] Cf. Levy & Murnane (2013), p. 6

[102] Spath, et al. (2012), p. 47

Tasks performed by human in manufacturing

To understand how digitization affects workforce, the economists Autor, Levy & Murnane have categorized human skills in to 5 groups and analyzed the computerization has altered job skills demand within 1969 to 1998:[103]

1. **Non-routine analytic tasks**
   To solve problems without rule-based solutions expert thinking is necessary. This requires pure pattern recognition, which means processing information that cannot be easily programmed on a computer. In this case, computers are actually not able to substitute human work, they effectively complement human skills by immediate information processing and supply. Levy and Murnane (2013) also refer this type of task as *Solving Unstructured Problems*.
2. **Non-Routine interactive tasks**
   Whenever it is necessary to interact with humans, complex communication skills are necessary. They are necessary to gather information and make sense of it, to explain it, or to persuade others of implications for action. Thus, it is also referred as Working with New Information.
3. **Routine cognitive tasks**
   These kind of mental tasks can be easily accomplished by following a set of deductive or inductive rules. Thus, they are at high risk of computerization.
4. **Routine manual tasks**
   Also physical tasks can be well described by deductive or inductive rules. They are also candidates for computerization since they are described as precise and repetitive movements.
5. **Non-routine manual tasks**
   If physical tasks cannot be defined by simple If-then-do rules, Autor, Levy & Murnane call them non-routine manual tasks. They often require optical recognition and fine muscle control. Computers are often not able to supplement or even complement human work in most of these tasks.

[103] Cf. Autor, Levy, & Murnane (2003), p. 1286; Levy, & Murnane (2007), pp. 14; Levy & Murnane (2013), pp. 16

Computer capital usually influences human workforce in two ways: [104]

1. Substitution human work if tasks can be accomplished when following explicit rules. This mainly refers to routine cognitive and manual tasks.
2. Complement human labor performing non-routine interactive or analytical tasks. Typical examples are problem solving or complex communications tasks.

Figure 8 shows a clear trend of rising non-routine analytic and interactive tasks. Routine physical and cognitive tasks, as well as non-routine manual tasks are declining since the 1970s.

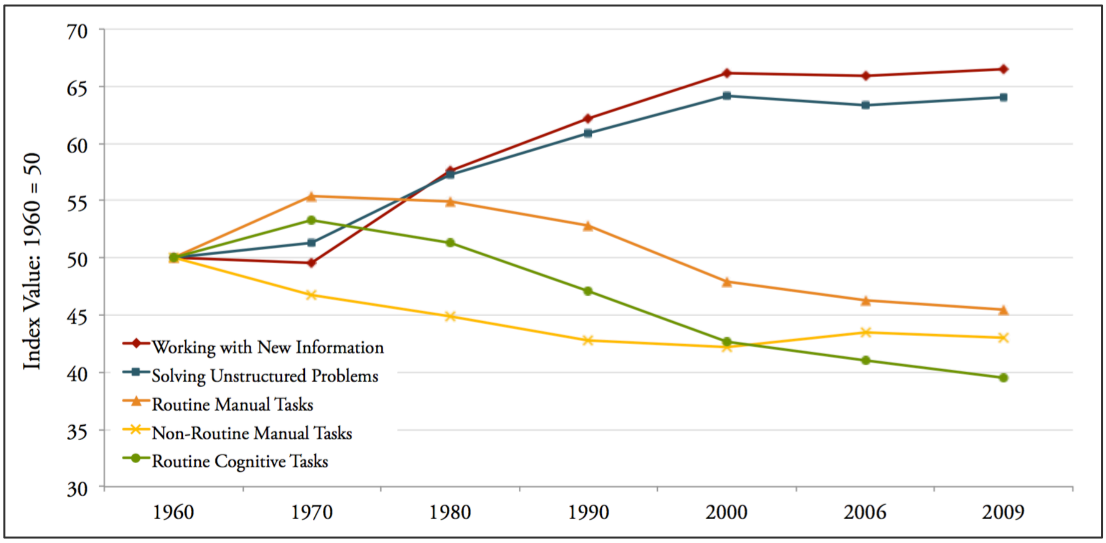

Figure 8: Index of changing work tasks in the U.S. economy 1960-2009[105]

This trend leads human to perform three kinds of tasks. People will have to solve unstructured problems, to work with new information and they will still carry out a number of non-routine manual tasks.[106]

Highly repetitive and exhausting tasks will be hand over to machines, while human are predicted to overtake more instructive tasks e.g. helping, guiding

[104] Cf. Autor, Levy, & Murnane (2003) p. 1279

[105] Levy & Murnane (2013), p. 18

[106] Cf. Levy, & Murnane (2013), p. 28

and maintaining a high number of machines at the same time.[107] It is conceivable that machines will be controlled on remote. Worker will receive messages on the smartphone and webcams will show production lines if problems occur. Instructions can be given from any place via secure internet connection, ensuring production to continue. This forecast implies production lines to be running 24/7 and shift models becoming obsolete.[108] In general, machines are predicted to mainly complement human tasks (especially non-routine analytic and interactive tasks) and additionally create new jobs in other related disciplines (e.g. IT or data science).[109]

Work regulations

To successfully transform an organization into an agile manufacturing company, also manufacturing workforce has to get agile.[110] Therefore, work regulations must adapt in terms of time regulations and flexible labor engagement.[111]

First studies suggest flexible time models will become normal. It allows workers to organize them self while production planning will directly adapt to changes.[112] In Germany, 72,1 percent of manufacturing companies, independent of company size or industry sector, already claim a serious need in widening the flexible work time regulations by government. They expect more shorthanded fluctuations on labor demand (see Figure 9).[113]

[107] Cf. Lorenz, et al. (2015), pp. 8

[108] Cf. Blanchet, et al. (2014), p. 8

[109] Cf. Levy & Murnane (2013), p. 6

[110] Cf. Vinodh (2011), p. 3256

[111] Cf. Spath, et al. (2012), p. 68

[112] Cf. BMWi (2015), p. 28

[113] Cf. Spath, et al. (2012), p. 73

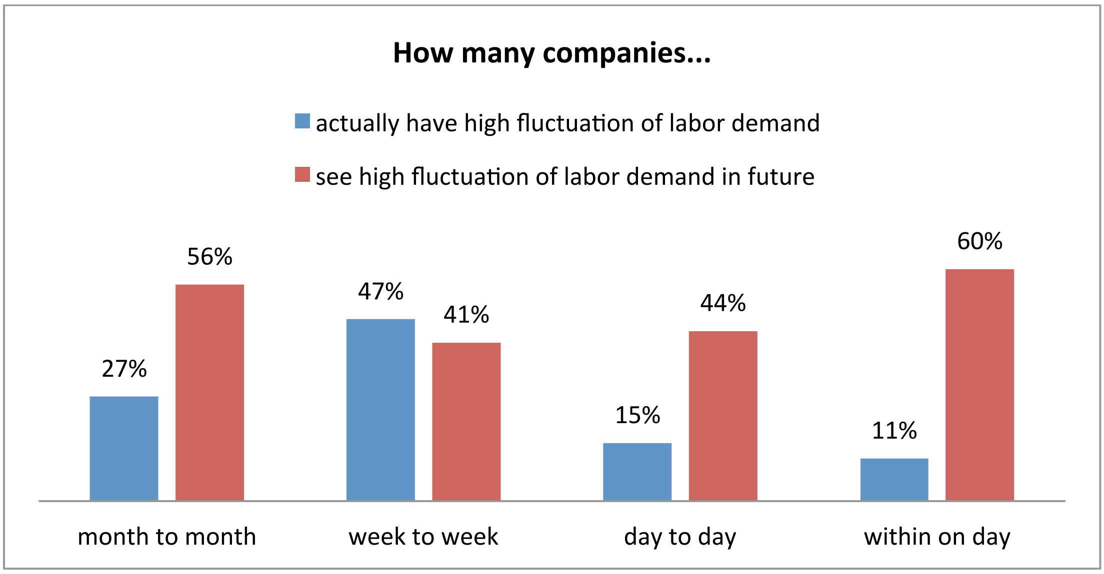

Figure 9: How companies expect fluctuations in labor demand[114]

Actually, working-time accounting, flextime, and home-office are the most common flexible working systems in German companies, independent of company size or industry sector.[115] As there are not much flexible work time regulations for these systems, subcontracted employments or contracts for work and services are more common than regular contracts to stay flexible.[116] Individual solutions depending on one workers stage of life, tasks and competencies will get more important.[117] It is also possible that machine operators will work for different companies on different days of the week.[118] In the end, aging workers and employees with family will benefit the most as they will perform less demanding physical work and have greater flexibility.[119]

2.2 A changing workforce

As discussed within the last chapter, digital manufacturing technologies are predicted to become increasingly important keeping manufacturing companies competitive. These technologies strongly rely on the guidance of

[114] Illustration based on Spath, et al. (2012), p. 5

[115] Cf. IFO (2012), p. 5

[116] Cf. Spath, et al. (2012), p. 74

[117] Cf. Schlund, Hämmerle, & Strölin (2014), p. 24; Spath, et al. (2012), p. 74

[118] Cf. Lorenz, et al. (2015), p. 13

[119] Cf. BMWi (2015), pp. 28

human workforce, which will be responsible for non-routine analytical, cognitive and manual tasks.

Due to the demographic change, companies are facing new challenges in dealing with an aging workforce and their changing education and job requirements. There is potential exposure through the difficulties encountered in developing an adequate skilled manufacturing workforce. The following sub-chapters aim to analyze the impact of the demographic change, with special focus on employees work life and education needs.

2.2.1 The demographic change

The Rate of Natural Increase (RNI) is declining on a global range (see Figure 10). As the graphs show, more developed countries are at a higher risk of negative total population growth. As an example, Japan is already exhibiting negative growth rates, but the RNI of less developed regions is also declining since years.[120]

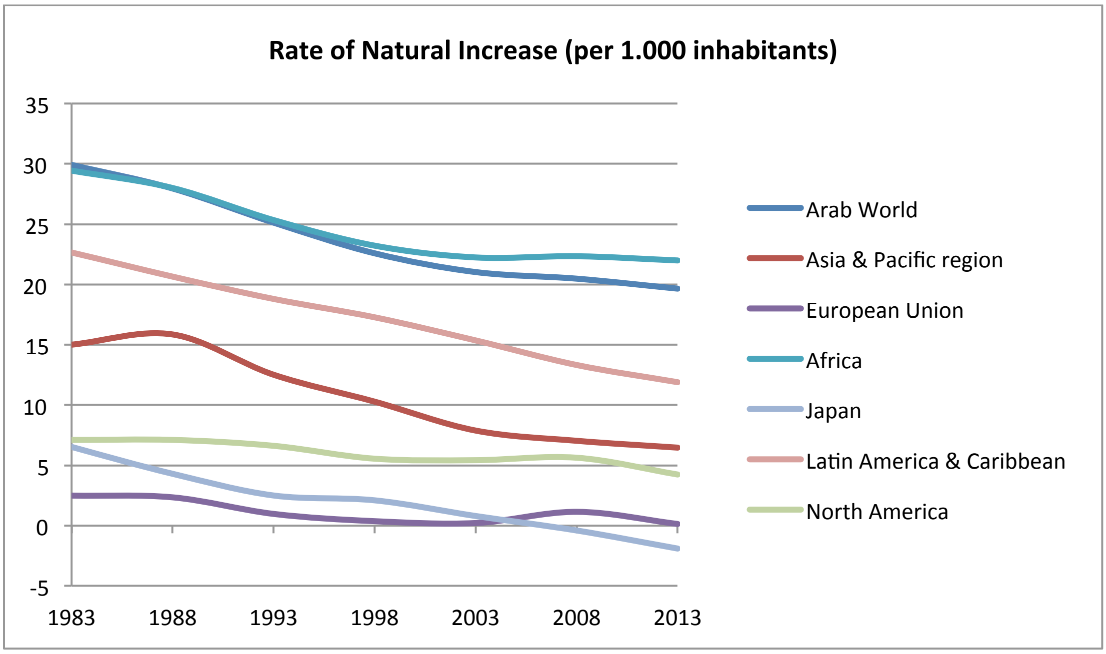

Figure 10: Development of the Rate of Natural Increase within past 30 years[121]

[120] Based on data retrieved from http://data.worldbank.org/indicator [22.01.2016]

[121] Illustration based on data retrieved from http://data.worldbank.org/indicator [22.01.2016]

As a consequence, the number of 55+ workers will increase dramatically to maintain or raise Gross Domestic Product (GDP) and ensure continuation of the social security standards.[122]

Thus, individual capabilities of aging employees (e.g. physical capabilities, willing to learn, etc.) must be considered in future manufacturing concepts in terms of flexible work arrangements, suitable training and development, and appropriate workplace design.[123]

This trend will also affect manufacturing companies, as they will lose employees and thus skills and knowledge due to earlier retirement. As an outcome, a dramatic decrease in potential workforce and know-how is predicted.[124]

2.2.2 Four generations and their expectations of work

Thinking about the future workforce in year 2035 and beyond, there are at least three generations expected to work together.

Generation X was born between 1961-65 and 1975-83 and thus will be between 58 and 74 years in 2035. The subsequent generation has many names, e.g. Generation Why, Generation Me, Millennials, Digital Natives or the Do-or-Die Generation. Usually it is referenced as Generation Y and describes the cohort born between 1976 and 2000, which reflects an age of 35 to 59 years in 2035. Since 2000, newborns refer to Generation Z, which will be younger than 35 years in 2035. If the Baby Boomers Generation still has to work in 2035 and thus outline a fourth Generation working simultaneously is questionable. Depending on various regulations such as e.g. retiring age but also the health of the individual employee, this option is considered within this thesis. The Baby Boomers Generation refers to the post war generation and earned this name because they raised birth rates dramatically. Literature refers this generation is born between 1940-46 and 1960-64.[125]

[122] Cf. Buyens, et al. (2009), p. 103 ; Dobbs, et al. (2012), p. 38

[123] Cf. Streb, Voelpel, & Leibold (2008), p. 2; Van Dijk, Dewilde, & De Vos (2009), p. 104

[124] Cf. Streb, Voelpel, & Leibold (2008), p.2 ; Wanger, Weber, & Fuchs (2013), pp. 336

[125] Cf. Berkup (2014), pp. 222; Holste (2012), pp. 20; Srinivasan (2012), pp. 51

As Figure 11 shows, the date ranges but also the names of the different generations are slightly changing within literature.

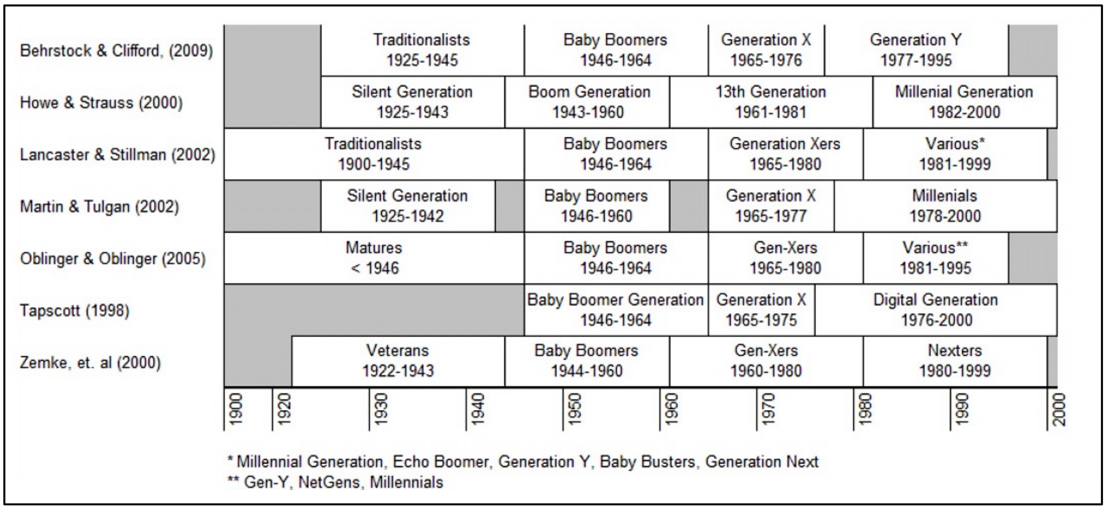

Figure 11: Labels and date ranges of generations according to various authors[126]

The characteristics of the different generations according their private life, work life, and learning style is expected to change dramatically between the generations and therefore an important topic to discuss within the next sub-chapters.

Baby Boomers

Related work life, this generation is defined as being benefit oriented, consistent, and very relevant to one's job. They live to work, are status and performance oriented. Baby Boomers are striving for fairness, are used to teamwork and discussions and work in a clearly structured way.[127]

Power and authority are important attributes to define their careers. They measure job achievement and commitment by working hours. Usually, they get motivated with money and bonuses, or gaining prestige and status symbols.[128]

[126] Bledsoe, et al. (2014), p. 46

[127] Cf. Holste (2012), p. 19

[128] Cf. Berkup (2014), p. 221

Generation X

This generation is often referred as realistic, self-reliant, independent and techno-literate. Literature reproaches them as being aimless and apathetic. They are following traditional values but e.g. marriage and faith are not that relevant anymore.[129]

The Generation X works to live. They are searching for good balance between work and leisure, because that's what they were not used to due to their working parents. They are also the first generation able to think global because the first time in history, every place was considered to be accessible. In organizational structure, they prefer flat hierarchies. Authorities and authority leadership style is considered negative. Additionally, they are referred as being very self-reliant.[130]

Generation Y

Generation Y was brought up in the era of globalization, employment outsourcing and proliferation of Information and Communication Technologies. They are globally educated, self-confident, optimistic and highly goal oriented. Work-live balance is increasingly important and they have high expectations about their employers, but also of themselves. Against the Baby Boomers' "live to work" and the Generation X's "work to live" approach, these two generations mix up work and private life in terms of time and space, by e.g. Home Office. They usually challenge authority, dislike hierarchy and are not impressed by title or position.[131]

Due to the open-minded education they are respecting other races, sexes, cultural values or sexual choices and have no problems in cooperating with those in business live. They also have the ability to focus on more than one job, fulfill their work very quickly and are open to change. This is also why they change jobs more often than other generations.[132]

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[129] Cf. Holste (2012), p. 20; Srinivasan (2012), pp. 51

[130] Cf. Holste (2012), p. 20; Srinivasan (2012), pp. 51

[131] Cf. Berkup (2014), pp. 222; Holste (2012), pp. 20; Srinivasan (2012), pp. 51

[132] Cf. Holste (2012), p. 20; Srinivasan (2012), pp. 51

Generation Z

This generation is today not into work life and thus their needs and expectations about jobs are difficult to define.[133]

First studies show members of the Generation Z are self-confident and understand working has an important role to make true their dreams. Social environment and team spirit is important. Happiness in business life is necessary, otherwise they would quit jobs very easily.[134]

As they are born within the era of extensive ICT development, they are used to digital technologies and quick and instant information exchange. They are concentrated and interested in more than one subject at the same time und thus capable of multitasking. The upcoming generation is expected to be creative and innovative, having a global point of view, preference of non-standard and personalized work and tend to be highly efficient.[135]

2.2.3 Generation-specific aptitude to digital technologies

When comparing the different generations regarding their aptitude to digital technologies, noticeable differences can be identified. Starting with the generation of Baby Boomers, the biggest technology innovation was the Personal Computer (PC). This went further with the development of mobile phones and the internet during Generation X, the commercialization of the internet and development of laptops in times of Generation Y and the development of smartphones, apps, mobile services and social networks within Generation Z.[136]

Thus, Generation Z is literally born into the era of connected devices. They know how to handle smartphones and tablets since they were babies. Thus, mobile technologies and social networks have become an important part of their live they use every day. [137]

[133] Cf. Holste (2012), p. 21

[134] Cf. Ozkan & Solmaz (2015), pp. 479

[135] Cf. Berkup (2014), pp. 223

[136] Cf. Holste (2012), p. 22

[137] Cf. Berkup (2014), pp. 223

Generation Y is also highly used to connected devices and social networks, in both private and work life. They use them to get support and direct feedback on their activities, as well as networking and recruiting platforms.[138]

Generation Z and Generation Y are likely to use digital technologies helping them to accomplish their goals. They use them to gather information and solve common problems within their jobs and private. To these generations, it is important to use up-to-date technologies as they view it as tool to fulfill better work. Against that, Generation X utilizes technology only if necessary. This generation uses the internet mainly for research activities, whereas younger generations also utilize the internet to e.g. create databases and networks.[139]

Older workforce (especially the Baby Boomer generation) has problems in understanding new technology. As they are not used to it, multitasking with technology seems to be a problem. This also leads to frustration and reluctance to adapt.[140]

To avoid this, it is important to show them the benefits of new technology and how they can use it for their own benefits.[141]

2.2.4 Other generational differences

Additional to the generations' aptitude to digital equipment, there are also other more general aspects to be considered. This is less depending on the generations itself but on the age of employees.

Individual physical and mental skills are naturally changing within ones live and thus affecting productivity. Skills like muscle strength or faculty of sight tend to decrease with rising age, whereas language skills usually stagnate, social competence and judgment skills usually improve.[142]

[138] Cf. Holste (2012), pp. 20; Srinivasan (2012), p. 52

[139] Cf. Berkup (2014), pp. 222; Ozkan & Solmaz (2015), p. 480

[140] Cf. Bledsoe, et al. (2014), p. 50

[141] Cf. BMWi (2015), p. 28

[142] Cf. Becker (2015), p. 26

2.2.5 Education needs for future workforce

Generation Z has access to up-to-date Information and Communication Technologies (ICT) 24/7. Including these technologies into education has high potential to bring them more into learning and additionally reduces classroom time, which gives them more time making sense out of information surrounding them. This doesn't mean classes must move completely online. Face-to-face interaction is still crucial to students, especially in primary and secondary education.[143]

Education needs of older workforce are rarely researched and best practice examples are uncommon. Many 55+ workers actively search for further training opportunities, but often they resist learning new skills or do not agree training improved their skills.[144]

Older workforce prefers training sessions in small groups or even one-on-one training. Studies show that even if they need more time to learn, finally they use the learned knowledge more effective. This refers to the high potential to self-paced training sessions for older workers. Also clear instructions and quick feedback can improve the workers training progress.[145]

To train both young and old workforce, the development of "benefit partnerships" is suggested. This training method is handled in traditional mentoring style including knowledge transfer in both directions. Thus, younger employees get access to extensive experience and older workers get taught in most recent technical developments.[146]

Advantages of digital technologies in classroom

Using computers in early educational stages proved to be very successful. It raised learners motivations by receiving feedback from a non-judgmental machine, improved student's writing skills due to spelling and grammar checking tools and improved their problem solving skills. Actual technological

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[143] Cf. Rosen (2011), pp. 13

[144] Cf. Koc-Menard (2009), pp. 334; Ravichandran, et al. (2015), pp. 157

[145] Cf. Ravichandran, et al. (2015), p. 159

[146] Cf. Koc-Menard (2009), p. 335

leaps e.g. iPad and mobile connectivity are helping teachers to remodel the learning environment. Learners get the chance of independent learning and technological aids support individual learning styles.[147]

Disadvantages of digital technologies in classroom

Using these kind of technologies has also negative sides. Looking enhanced time on screens (e.g. of mobile phones, computers or iPads) can affect students' ability to focus on details and may shorten their attention span. Also social gaps can arise between people who have access to these technologies and those who have not, but also between generations who have the skills to deal with these technologies and who's not.[148]

2.2.6 Adult vocational training in Austria

Following the trend of digitization as described in chapter 2.1, technological improvements are evolving in shorter time intervals and increasingly unpredictable. Therefore, it is important for workers to make sure they are learning continuously over their whole life.

Lifelong learning includes all learning activities continuously undertaken to improve knowledge, skills and competence. The following definitions of learning activities are important to understand the content of lifelong learning:[149]

1. Education provided within regular systems of schools, universities, colleges and other institutions is called **formal education**. It usually provides continuous full-time education for children and younger people and is often completed by the age of 25.
2. Organized and sustained educational activities which are not covered by the definitions of formal education are referred as **non-formal education and training**. These programs must not necessarily take place within educational institutions. Educational programs for persons of all ages are covered within these programs. They may include adult

[147] Cf. Miniawi & Brenjekjy (2015), p. 1476

[148] Cf. Miniawi & Brenjekjy (2015), p. 1477

[149] Cf. Goglio & Meroni (2014), pp. 4

literacy, basic education for out-of-school children, life skills, work skills and general culture. Also private lessons with teachers or tutors are included, e.g. piano lessons of foreign languages.

3. **Informal learning** describes self-learning approaches, which are often unstructured and outside of formal education institutions. They include computer-based learning/training and web-based education, but also printed material e.g. visiting libraries. This type of education is not often covered within statistics.
4. Another important definition to understand lifelong learning refers to **continuing vocational training**. it includes training measures and activities which aims to build new competencies, or to develop and improve existing ones. Enterprises have to (at least partly) finance these sessions for their employees who either have a working contract of who benefit directly from their work (e.g. unpaid family workers and casual workers). Employees within apprenticeships and training contracts are not taken into consideration.

Also governmental initiatives have identified the needs of lifelong learning. The Center for Research on Education and Lifelong Learning (CRELL) was established to achieve the European community objectives in the *Lisbon Agenda* and the *EU2020 agenda*. They provide expertise in the fields of economics, econometrics, education, social sciences, statistics and research. CRELL's main activities include indicator-based evaluation and monitoring of education training systems.[150]

To identify the differences between European countries, a benchmark for lifelong learning (LLL) has been established. It measures the vocational education and training participation of 25 to 64 year olds. The main goal of the European Union is an average participation rate of 15% till 2020. In 2013, Austria already reached a share of 14%, which is in upper midfield level compared to the rest of European states. [151]

[150] Cf. https://crell.jrc.ec.europa.eu/ [29.01.2016]

[151] Cf. Statistik Austria (2015), p. 66

Taking a closer look into the data, clear differences between different age, formal education level and gender can be identified.[152]

1. The participation rate to vocational training falls when people get older. Within the groups of 15 to 24, 25 to 34 and 35 – 44 year olds, the participation rate decreases slightly (at maximum 0,7%). 45 to 54 years olds participate at 1,5% less than the younger ones. The biggest drop can be identified between the group of 45 to 54 olds and 55 and older ones, which is 6,5%.
2. A more dramatic shift can be identified between different formal educational levels. The participation level of tertiary education graduates (which is 30,7%) is about six times higher than the participation rate of people who didn’t continue to secondary education (4,6%). In secondary education, apprentices take fewest trainings (7,9%), against academic high school graduates, where 29,3% enroll in further education.
3. In general, women are more likely to attend vocational training. Especially in the group of 25 to 34 year olds.

To get a more detailed overview see Table 1.

[152] Cf. Statistik Austria (2015), p. 66

Table 1: Vocational training participation in Austria[153]

Description	Participation rate		
Overall	14,0%		
EU	15,0%		
Age	**All**	**Male**	**Female**
15-24 years	13,0%	12,3%	13,6%
25-34 years	12,8%	11,2%	14,5%
35-44 years	12,1%	10,5%	13,6%
45-54 years	10,6%	9,1%	12,1%
55+ years	4,1%	3,4%	4,7%
Educational Level	**All**	**Male**	**Female**
Compulsory Schools	4,6%	4,7%	4,6%
Apprenticeships	7,9%	7,5%	8,5%
Vocational Schools	11,8%	10,4%	12,5%
Academic High Schools	29,3%	31,1%	27,8%
Vocational Schools with higher education entrance qualification	20,5%	17,6%	23,3%
Academia	30,7%	27,4%	33,5%

As a result of European Union survey in 2010, Austria has been identified in having the second highest rate of companies actively providing or supporting their employees with continuing vocational training. A study conducted in 2013 reports that employees are also motivated to take the courses and trainings outside their working hours. Trainings conducted during work time make the highest part (45,1%), about a third of all training sessions where conducted in free time (19,1%).[154]

[153] Cf. Statistik Austria (2015), p. 67

[154] Cf. Statistik Austria (2015), pp. 66

2.3 Education methods

Compared to machines, human still have advantage in areas like ideation, large-frame pattern recognition or the most complex forms of communication, and it seems likely to hold on for some time. The problem identified by researches is these are skills education typically is not focused on. Common education concepts focus on memorizing facts, reading, writing and arithmetic. Unfortunately, these skills are main attributes of digitized equipment.[155]

In the next chapter, basic concepts of learning and thus possible education concepts to develop these skills are discussed.

2.3.1 Basic of didactics

The word didactic has the origin in the Greek word “didáskein” which means “to teach”.[156] It refers to the theory and practical implementation of learning and teaching methods.[157] The aim is to answer the questions who, what, by whom, when, with who else, where, how, by what and why learning is necessary.[158]

Didactics in a narrow sense often refers to the definition of learning objectives and content. In a broader sense, didactics also cover learning methods and therefore applicable or used media.[159]

To describe learn-teach processes, we can distinguish between the target oriented dimension describing what and why should be taught, and the path oriented dimension to describe how to teach and learn.[160]

In general, didactical concepts can be described as generic didactics, which constrain to general structural models for teaching without consideration of

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[155] Cf. Brynjolfsson & McAfee (2014), p. 194

[156] Cf. Arnold & Roßa (2012), p. 1; Riedl (2004), p. 8

[157] Cf. Riedl (2004), p. 8

[158] Cf. Rebmann, Tenfelde, & Schlömer (2011), p. 197

[159] Cf. Riedl (2004), pp. 8

[160] Cf. Riedl (2004), p. 8

specific professional fields. Against that, subject didactics aims to actively design courses with focus on specific professional fields.[161]

2.3.2 Didactical concepts

The following sub-chapters provide a brief overview of a number of didactical concepts referred to hands-on experiencing and occupational education. Because of the high number of existing didactical concepts, these examples do not constitute a full list.

Experiential learning

According to Kurt Lewin, the process of learning is established when alteration between specific experience and analytic distance is given. John Dewey and Jean Piaget highlighted gaining experience through practical exercising as key factor for cognitive development.[162]

Building on this, Kolb (1984) describes the learning process as a circular process logically following four phases (see Figure 12). According to Kolb, every cycle generates a new cycle, thus every end represents a new start.[163] It describes a dynamic view of learning driven by the resolution of dual dialectics of action and reflection as well as experience and abstraction.[164]

[161] Cf. Rebmann, Tenfelde, & Schlömer (2011), pp. 197

[162] Cf. Markowitsch, Messerer, & Prokopp (2004), p. 28

[163] Cf. Markowitsch, Messerer, & Prokopp (2004), pp. 28

[164] Cf. Kolb (2014), pp. 50

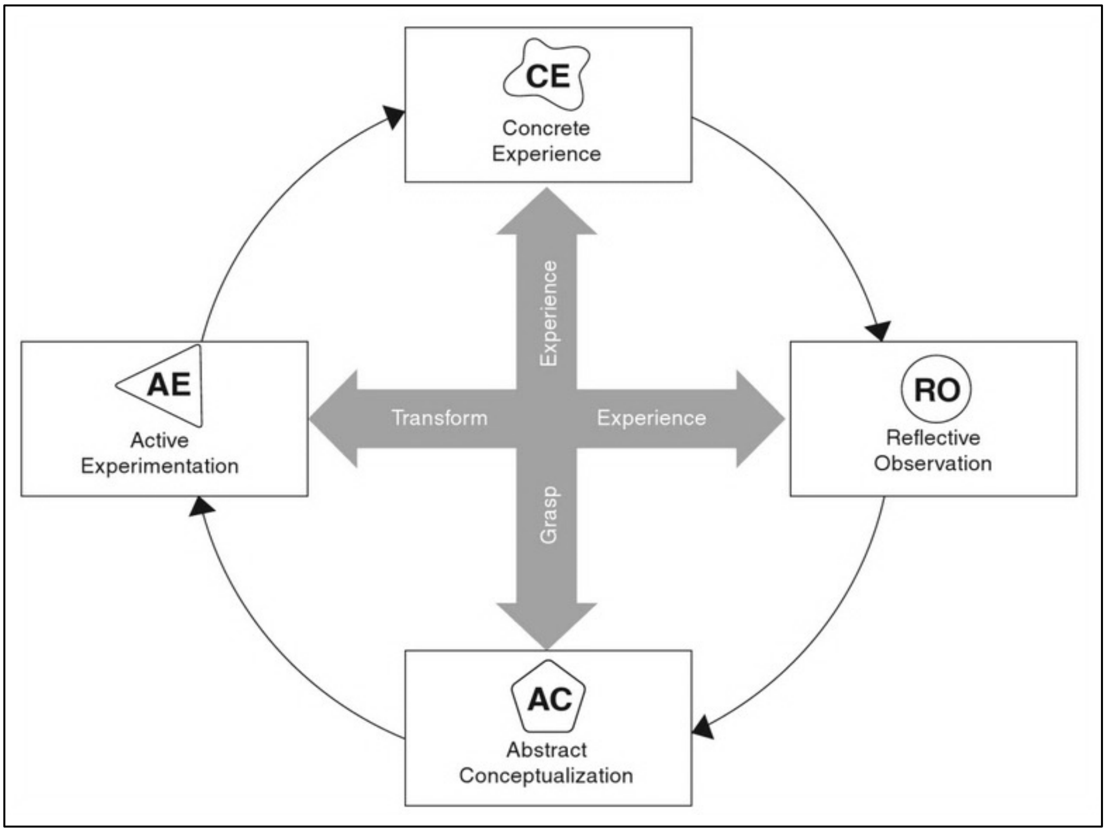

Figure 12: Kolb's experiential learning cycle[165]

Kolb refers gaining knowledge as a process of grasping information and transforming experience, which can be described as individuals' interpretation and acting on information. Concrete Experience (CE) and Abstract Conceptualization (AC) describe grasping experience. Active Experimentation (AE) and Reflective Observation (RO) refer to transforming Experience. An idealized learning cycle would consist of experiencing (CE), reflecting (RO), thinking (AC) and acting. The implied resolution of creative tensions within the cycle is what creates the learning effect.[166]

Additionally, Kolb derives four different learning styles out of this cycle, each with certain strengths and weaknesses. The convergent style focuses on the development of problem solving, decision-making skills and the realization of ideas. Against that, learners with higher creativity and social skills refer to the divergent learning style. Analytical thinking, observation and arguing is focus

[165] Cf. Kolb (2014), p. 51

[166] Cf. Kolb (2014), p. 51

of the assimilating learning approach. The accommodative learning style refers to the trial-and-error approach, which implies concrete experience through active experimentation. Depending on the required skills and the individual's needs, different learning styles are preferable.[167]

Experiential learning is referred as the foundation for a high number of learning methods e.g. project-oriented learning, case-based learning, problem-oriented learning or action learning.[168]

Project-based education

Within project-based education, interesting real life problems that require them to gather information and think critical and serious captures students. Usually, a project is represented by a problem to solve, a phenomena to investigate, a model to design or a decision to make.[169]

The didactical concept of project-based education is strongly related to experiential learning.[170] It emphasis interdisciplinary cooperation within groups and forces a relation to reality. Typically, project-based education systems are mixtures of various didactical concepts such as e.g. self-organized learning, collaborative learning or problem-oriented learning. [171]

The project-based education concept consists of several core elements. In a first step, the learners must get interested and engaged into the topic. Fundamental information is necessary, as furthermore the learners have to develop a project plan. After working on the project, it is usually reviewed and feedback gets provided.[172] Within these steps, students acquire experience by practicing and experimenting while they are independently creating certain projects.[173]

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[167] Cf. Markowitsch, Messerer, & Prokopp (2004), p. 30

[168] Cf. Markowitsch, Messerer, & Prokopp (2004), p. 32

[169] Cf. David (2008), p. 80

[170] Cf. Markowitsch, Messerer, & Prokopp (2004), p.32

[171] Cf. Markowitsch, Messerer, & Prokopp (2004), p. 80

[172] Cf. Efstratia (2014), p. 1258

[173] Cf. Krajcovicova & Capay (2012), p. 855

By project-based education, learners are exposed in learning mainly soft skills such as teamwork, conflict management, decision-making and communication skills.[174]

Self-organized learning

Sugata Mitra, an Indian educational researcher, was a teacher in New Delhi. While teaching children of rich parents how to program a computer, he always thought about how will poor children in slums ever learn how to use a computer and write programs. Starting the project *"Hole in the Wall"*, he tore a hole into the boundary wall of the slum next to his office and put a computer inside. After a while, he came back, catching children - some of them between six and eight years olds - who have never seen a computer and never learned English before, surfing the internet and teaching others how to use it. He repeated this experiment in various small villages in India and always earned the same results - kids where teaching themselves English, and how to use the computer. This was the first time Sugata Mitra heard the phrase "teach ourselves" in an educational context.[175]

By definition, self-organized learning describes a process of learning, where learners are defining the learn process for their own. Self-organizing can refer e.g. to learn-content, learn-target, learn-organization, learn-control, etc. Coaches, who design the content or accompany the process, support often students. Thus, self-organized learning aims to promote the learners' competence to act and should be applied as extend for something known.[176]

Self-organized learning is often included in other didactical concepts. This includes the majority of practical oriented methods such as e.g. action-oriented learning, project-oriented learning, problem-oriented learning or case-based education. It does not necessarily have to be applied as an individual learn practice, it can be also applied within a collaborative learn practice.[177]

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[174] Cf. Krajcovicova & Capay (2012), p. 855

[175] Cf. https://www.ted.com/talks/sugata_mitra_build_a_school_in_the_cloud [11.02.2016]

[176] Cf. Markowitsch, Messerer, & Prokopp (2004), p. 39

[177] Cf. Markowitsch, Messerer, & Prokopp (2004), p. 42

By the help of self-organized learning, students are achieving higher levels of self-regulation. It helps them to assess their own learning and control their understanding.[178]

As an outcome, students are often completing their learning tasks better, they are more motivated and thus more successful in school.[179]

Collaborative learning

Collaborative learning describes an environment where students learn in smaller groups to reach a certain goal together. Usually, teachers and coaches support these groups. One output of this approach is the development of social skills. This includes the ability to work in teams, but also to recognize and accept the diversities between team members. On the other hand, the learners are claimed to actively participate in the group to bring in their ideas and knowledge. Thus, also their intellectual capacities and self-confidence get developed further. [180]

In general, three different types of learning groups are distinguished.[181]

1. **Informal learning groups** are formed to instantly work together for a very short time, mainly in an unstructured way.
2. For medium length time slots **formal learn groups** are build. These are usually more structured and responsible to perform bigger tasks such as experiments, projects or the preparation of scientific papers.
3. **Long-time learning teams** usually collaborate over the entire course length or a complete semester. These groups often use regular meetings, also in free time, to learn, read and work together on certain tasks. These types of learn group are often self-organized and does not necessarily require a coach.

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[178] Cf. Jakesova & Kalenda (2015), p. 180

[179] Cf. Jakesova & Kalenda (2015), p. 187

[180] Cf. Markowitsch, Messerer, & Prokopp (2004), pp. 47

[181] Cf. Markowitsch, Messerer, & Prokopp (2004), pp. 47

Whenever a team performs a task together, the evaluation of the results with respect to the teams and individuals performance is important. Therefore, it is crucial that the evaluation of the results is continuously executed over the total process. The coaches but also other teams and learners should provide feedback. The evaluation should contain contextual and group-dynamic processes. Both group and individual performance should be measured over the whole process. This could also happen within the final evaluation by adding extra points for group results to the individual results. [182]

Action-oriented education

Education is defined action-oriented if participants are able to gain and transform information into experience by using also their limbs and their senses additional to their brains. Thus, theoretical and practical work stands in a balanced ratio.[183]

Action-oriented education is always tied to specific working situations and thus can be seen as a basic foundation to build comprehensive job-related competencies such as planning, implementing and evaluating. This education method uses self-organized learning principles by letting students configure their own learning process by handling complex statements as complete tasks. To model the learning settings as closely as possible to actual working context, the content must have a high degree of realism and clarity. [184]

To successfully develop the skills of the learners, action-oriented education has to fulfill certain characteristics. The individuals' interests are seen as initial knowledge base and additionally give the learners the opportunity to reflect them and develop them further. They are encouraged to fulfill their tasks independently and set to set their own pace. Knowledge and hands-on work must stand in a balanced ratio. Learners should act in a solidary way, which can be achieved when verbal communication and targeted work is coordinated well. Additionally, the participants must be able to identify with

[182] Cf. Markowitsch, Messerer, & Prokopp (2004), pp. 47

[183] Cf. Jank & Meyer (2011), p. 315

[184] Cf. Cachay, et al. (2012), p. 1146

the product. This ensures students are able to actively enroll in class and thus can easier and consciously work on the development of their methodological competencies.[185]

Case based learning

The basic idea of case based learning is to confront students with specific real life situations (the *case*) that real people and organizations have faced. The learners are asked to step into the shoes of the protagonists, to analyze their challenging situation and discuss it in class.[186] This method challenges the students analytical and communication skills. They must give the case a meaning by identifying it's key issues and questions and to come up with conclusions, considering all gaps and uncertainties that are also present in real life situation.[187]

What differs case based learning from common classroom education is the way content and knowledge is transferred. Usually, a teacher stands in front of a class, transferring information to the students, which is very effective to transfer content but doesn't encourage students to think about it. In case based learning students do not receive the knowledge, they make the knowledge, assisted by experts (case instructor). The instructor is responsible to sustain the class discussion but rarely deliver his expertise. He has to ask the right questions at right time, giving feedback and to uphold the discussion. Most content is provided by the students itself. They must be well prepared to make meaning out of the case. Cases are filled with facts and information but do not lead to a single "truth". The students themselves are responsible for the outcome of the discussion and thus the knowledge transferred.[188]

The case content to analyze can differ from single individuals or organizations to entire nations or the world. It can be one-pagers or documents containing fifty or more pages. The important feature of cases is

[185] Cf. Jank & Meyer (2011), pp. 316

[186] Cf. Hammond (2012), p. 1; Markowitsch, Messerer, & Prokopp (2004), p. 67

[187] Cf. Ellet (2007), p. 6

[188] Cf. Ellet (2007), pp. 7

their purpose to represent the reality and to convey a real life situation with all its irrelevancies and information gaps.[189] In general, we distinguish between three kinds of case studies, which are discussed in class.

1. The **decision cases** ask students to solve specific dilemmas, conflicts or problems faced by the protagonists. They usually start with the description of the decision faced by the protagonist, following by asking the learners to identify distinct decision options and decision criteria. Students are asked to choose, proof and critique alternatives with arguments and evidence.[190]
2. In **problem cases**, students are also asked to step into the shoes of the protagonists and make recommendations and decisions, very similar to decision-forcing cases. The difference to decision-forcing cases is they don’t provide clear alternatives from which the learners choose. The specific problem is described from the protagonists’ view and challenges students to invent and defend their action plans for dealing with the problem.[191]
3. The third type of case study is called **evaluation case**. Sometimes this type is also called best-practice or worst-practice case. Evaluation refers to the value of effectiveness of any performance, act, or outcome. This doesn’t include a certain problem or a decision to make, but students are asked to discuss the bottom-line assessment. They must look at the factors supporting and opposing this statement and any that fall in between to provide a clear assessment.[192]

Because of the learners’ different knowledge, experiences and attitudes, the proposals will differ significantly in how to deal with the problems, interdependencies, organizational needs and the impact of a decision on the organizations departments. They strongly depend on the product, the company or the industry sector. Often there is not the one right solution, but this helps managers to identify the real problems and to ask the right questions about it. Participants learn how to deal with the situation of an

[189] Cf. Ellet (2007), p. 13

[190] Cf. Ellet (2007), pp. 135

[191] Cf. Ellet (2007), pp. 119

[192] Cf. Ellet (2007), pp. 163

unavoidably uncertain future and the implied challenges in making critical decisions that directly affect business success.[193]

Problem-oriented learning

Within this education method, the students gain knowledge by detecting and solving problems. It is mainly used within small groups of five to twelve people and an additional coach or tutor. The content should be built in an interdisciplinary manner including active and self-reflecting participation.[194]

Learners get confronted with a messy situation they have to analyze. In a first step they have to define the certain problem they are working on. Often, this is not clearly identifiable. In a next step, they have to identify the steps necessary to find a solution. Students have to organize this process for themselves, including researching and experimentation to acquire knowledge to solve the problem.[195]

Characteristics of problem-oriented learning can be found in most didactical concepts. The unique characteristic of self-oriented learning is that learners do not get any theoretical content before starting with the project. Thus, additional to the self-created and organized theoretical context, his type of education develops social skills such as critical thinking, teamwork capabilities and problem solving skills.[196]

Cognitive apprenticeship

The cognitive apprenticeship approach aims to transfer the approved craftsmanship learning method into school education.[197] According to Collins, Brown, & Holum (1991), it refers to the natural learning and teaching

[193] Cf. Beckisheva, Gasparyan, & Kovalenko (2015), p. 292; Gudmundsson (2015), pp. 6; Hammond (2012), pp. 1

[194] Cf. Markowitsch, Messerer, & Prokopp (2004), pp. 85

[195] Cf. Markowitsch, Messerer, & Prokopp (2004), pp. 85

[196] Cf. Markowitsch, Messerer, & Prokopp (2004), pp. 85

[197] Cf. Markowitsch, Messerer, & Prokopp (2004), p. 118

processes. As an example, to teach children how to speak, parents show them by talking to them, then helping them to talk on their own.[198]

The central processes behind the concept of cognitive apprenticeship can be described by observation, coaching and successive approaching of the observed content. This content can include domain knowledge (basic facts), heuristic strategies, [199]. control strategies and learning strategies. Additionally, learners develop skills in self-control and improved text apprehension.[200]

Game based learning

Learning by playing games is an emerging educational concept that aims to make knowledge accessible on a wide range of potential players. What makes games extremely effective is their ability to create systems in which players are allowed to test and experiment. It also encourages learning through failures by making failures that may not be acceptable in real business.[201]

A business game usually consist of three major parts:[202]

1. A **role-play** in which learners must actively act and thereby influence the course of the game.
2. Learners have to follow certain **rules** e.g. time limits to simulate pressure in decision making.
3. A **simulation game** that promotes a highly realistic situation by the help of e.g. computer aided tools.

The game scenario should describe the company's specific organization, products and processes as realistic as possible. Real corporate data should

[198] Cf. Collins, Brown, & Holum (1991), p. 1

[199] Heuristic strategies are "tricks of the trades" and refers to what experts found out works very easily in practice with less effort, even if not applicable on all cases.

[200] Cf. Markowitsch, Messerer, & Prokopp (2004), pp. 119

[201] Cf. Ross, Fitzgerald, & Rhodes (2014), p. 431

[202] Cf. Markowitsch, Messerer, & Prokopp (2004), p. 133

be used to show realistic results within the tasks. Due to the use of real data, strong security requirements are given to avoid unauthorized access. The games should be easily adapted to further use.[203]

Before starting such a game, individuals must gain information about the initial situation and their roles. Teams get build and targets get defined. Relevant information is gathered within the next step and decisions about the solutions are elaborated. The teams go on to the simulation and execution phase, followed by a final evaluation and reflection part.[204]

What makes the game based learning interesting is the development of skills through "learning-by-doing", the appending motivation of a player due to win and fun situations and the ability to shape the content in which a player learns.[205] The learners gain experience in acting and decision making skills by practicing "what if" or "worst case" scenarios. They have to prove their knowledge under highly challenging boundary conditions such as time or cost pressure.[206]

2.4 Summary of literature review

Literature strongly indicates the trends of digitization and the demographic change are going to affect the future industrial workforce.

Digitization has clear similarities with past developments e.g. electrification or automation and thus implies major socioeconomic impacts.[207] The decrease in routine and non-routine manual tasks performed by human labor has already started decades ago and is not predicted to change.[208] Detailed predictions about future tasks and needed skills of the future industrial workforce have not been identified.

[203] Cf. Ahrens (2015), p. 279

[204] Cf. Markowitsch, Messerer, & Prokopp (2004), p. 134

[205] Cf. Ross, Fitzgerald, & Rhodes (2014), p. 431

[206] Cf. Markowitsch, Messerer, & Prokopp (2004), p. 133

[207] Cf. Brynjolfsson & McAfee (2014), pp. 100; Ford (2015), pp. 36; Syverson (2013), p. 38

[208] Cf. Levy & Murnane (2013), pp. 18

The demographic change is perceptible on a global range, already progressed to an advanced status in more developed regions. As a result, decrease in potential workforce and know-how is predicted.[209] Additionally, industry has to consider changing needs of future generation in terms of technologies used, individual treatment and work-live balance. Therefore, lifelong learning is considered as increasingly important to future workforce. This includes formal education, non-formal education and training and continuing vocational training.[210]

Basic didactical concepts are discussed to describe the process of learning being considered in evaluation of potential training methods. The investigated concepts strongly refer to hands-on experience as to its' high importance for occupational education.[211]

To adequately train the future industrial workforce, their role within the fourth industrial revolution must be identified. Actual and future job requirements in terms of tasks and needed skills, abilities and knowledge must be analyzed. Therefore, actual jobs at Magna Powertrain Plant Lannach get analyzed and expert interviews are conducted to identify future requirements and suitable training methods.

[209] Cf. Streb, Voelpel, & Leibold (2008), p.2 ; Wanger, Weber, & Fuchs (2013), pp. 336

[210] Cf. Goglio & Meroni (2014), pp. 4

[211] Cf. Markowitsch, Messerer, & Prokopp (2004), p. 28

3 Practical Approach

Before evaluating potential employee development methods, the actual and future tasks performed and skills needs of employees get identified.

A job analysis, based on a study of Frey & Osborne (2013), is conducted at Magna Powertrain Plant Lannach to give an example of the actual tasks and skills needs of manufacturing employees and it's risk of getting substituted due to digitization. Experts of Magna Powertrain support this analysis.

In a next step, the actual and future tasks and skills needs with respect to regional differences get identified and suggestions about future training models are designed. Due to the comprehensive content and global focus of this survey, a qualitative analysis in terms of expert interviews is approached.

As a result of the conducted expert interviews, potential future training methods are evaluated and analyzed by discussing them with experts. Finally, a framework to design future training methods gets created, supported by expertise of Magna Powertrain People Development and Training experts.

The following chapter describes the methods used within the practical part of the study.

3.1 Job Analysis

The job analysis is used to identify actual tasks of manufacturing workforce and derive actual skills needs. The goal is to identify the types of occupations employed at Magna Powertrain and the employment share of these occupations. Additionally, the risk level of getting substituted by digital manufacturing equipment of the identified jobs according to Frey & Osborne (2013) is investigated.

Literature on labor economics has mainly focused on the Dictionary of Occupational Titles (DOT), which was last revised in 1991. In 2010, the Occupational Information Network (O*NET) service has been developed as successor of DOT by the U.S. Department of Labor. Therefore, the O*NET service provides more recent information about occupational content and thus is used by Frey & Osborne (2013). [212] Therefore, the following job analysis is also build on the O*NET data.

The O*NET can be seen as the primary source of occupational information, a database containing hundreds of standardized and occupation-specific descriptions. This database includes a Content Model, which describes the knowledge, skills and abilities required to perform certain tasks, and the O*NET SOC Taxonomy, a spectrum of occupations, which defines a set of occupations across the world of work.[213]

By the help of the O*NET SOC Taxonomy the type and number of jobs within Magna Powertrain Plant Lannach get analyzed. The taxonomy includes 1110 occupational titles including 974 representing the O*NET data-level and thus are representative to this study. 23 Major Groups, 97 Minor Groups and 461 Broad Occupations classify the occupations.[214] In this study, these groups are used to evaluate the share of specific jobs within the organization. Due to the high number of occupations in the O*NET SOC Taxonomy and the very specific requirements of an automotive company, not all of the 974 occupation types are employed within Magna Powertrain Plant Lannach. The list is shortened to the indeed occupations of Magna Powertrain Plant Lannach and the number of employees occupied. Andor Paizer, Global Director Operational Support and Reinhard Schroffenegger, Assistant General Manager of Magna Powertrain Plant Lannach support this process. Title and description of the occupations are used to identify the risk of computerization according to Frey & Osborne (2013).

The five occupations at highest risk of computerization are used to identify and analyze the most important skills, abilities and knowledge of the actual workforce according to the O*NET Content Model. It describes the most important types of information about work and integrates them into a comprehensive system. This system reflects the character of occupations and people via job-oriented and worker-oriented descriptors. These are

[212] Cf. Frey & Osborne (2013), pp. 4

[213] Cf. http://www.onetcenter.org [05.02.2016]

[214] Cf. http://www.onetcenter.org [05.02.2016]

organized into six major domains that specify the key attributes and characteristics of workers and occupations. Figure 13 shows the six major domains and related subdomains.[215]

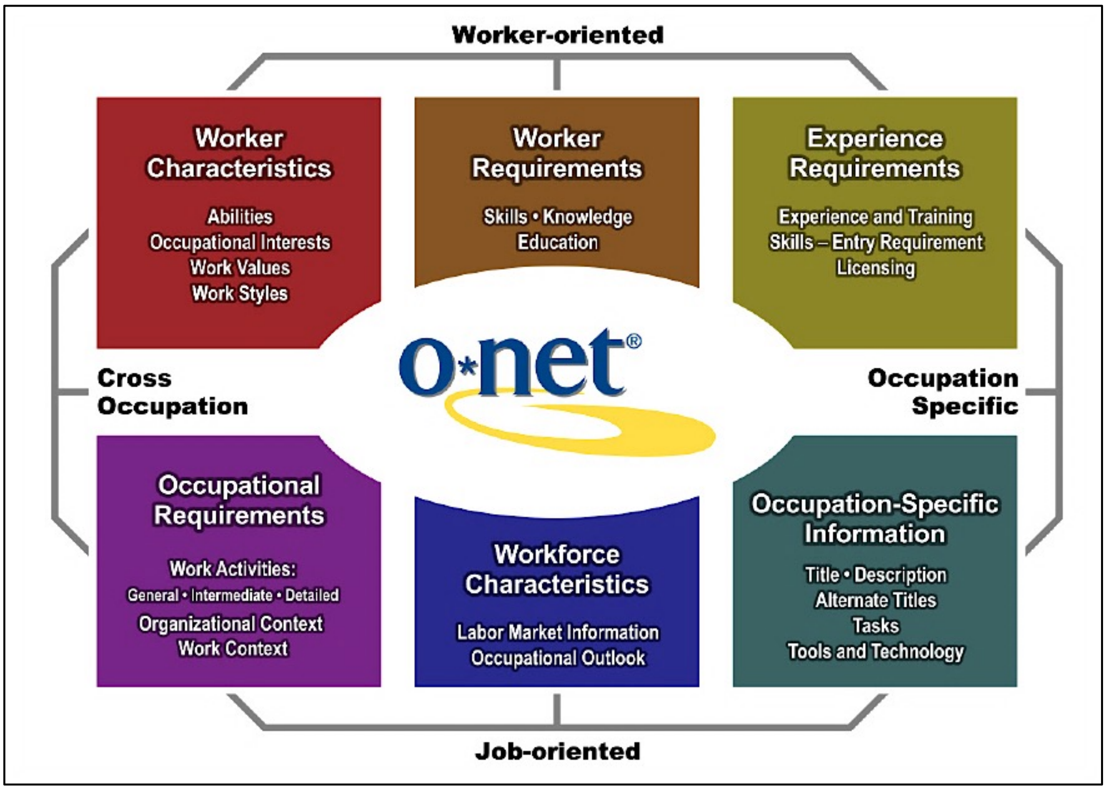

Figure 13: The O*NET Content Model[216]

In a final step, the actual skills of employees are compared on a global range. Therefore, interviews with actual and former Plant Managers of Magna Powertrain[217] of three countries are conducted. The methodology for this interview is described within the following chapter.

3.2 Expert interviews

To explore the actual situation and future developments of the workers' skills within the manufacturing industry sector as well as potential training methods, several expert interviews are conducted. Because of Magna's

[215] Cf. http://www.onetcenter.org [05.02.2016]

[216] http://www.onetcenter.org [05.02.2016]

[217] Equals the Magna internal job title "General Manager"

global presence, also the interviews are conducted with industry experts from various countries.

The interviews aim for comprehensive information acquisition on the investigated research topics. A census is not possible due to the high number of global experts and no given geographical boundaries. Instead, a partial survey is conducted.[218] Experts are chosen depending on their experience and their field of expertise inside and outside of Magna Powertrain. As per literature, the experts must be someone who either takes responsibility for design, implementation or monitoring of solutions for the investigated research question or problem, or has privileged access to relevant information.[219] They are located in Europe and U.S. Mainly face-to-face interviews are conducted. Due to large geographical differences some interviews are executed via telephone.

According to Bogner et al. (2014), semi-structured guideline interviews are conducted as they are most common methods within qualitative analysis.[220] Mainly open questions are used, allowing the expert to answer the question abundantly and additionally allowing the interviewer to ask into detail, depending on specific situation. Polar questions are also included. In these questions, the interviewees are asked to choose a number of given options, which results in a ranking. This includes simple yes or no answers as well as estimation questions. In case of telephone interviews the questionnaire is sent to the interviewee in advance to ensure polar questions can be answered effectively. Using literature and further discussions with the thesis supervisors identifies the given options. Additionally, interviewees are allowed to add certain answering options if necessary.[221]

Within the project, three interview rounds are conducted. The first interview round aims to identify actual skills level of employees. Therefore, actual and former General Managers of three Plants in Europe, Asia and North America are interviewed.

[218] Cf. Kornmeier (2007), pp. 158

[219] Cf. Meuser & Nagel (2002), pp. 71

[220] Cf. Bogner et al. (2014), p. 24

[221] Cf. Kornmeier (2007), pp. 169

Interviews with manufacturing and automotive industry experts are conducted to identify future tasks and skills needs of shop-floor workers, and potential future training models. Within twelve interviews, four of them are conducted with hardware fund leaders and successful start-ups in San Francisco Bay Area, four European automotive industry supplier experts and another four experts of Magna Groups.

The last interview round aims to verify the feasibility of emerging training methods and design training frameworks. Therefore, Human Resources People Development and Training expert are interviewed.

The next sub-chapters discuss the specific methods used within the single steps.

3.2.1 Actual skills level of employees

Building on the tasks performed by shop-floor employees, the actual skills level of Magna Powertrain gets analyzed. To identify the skills level of actual shop-floor employees in Magna Powertrain Plant Lannach, the evaluated tasks are analyzed due to their required skills. Plant leading experts Jürgen Schranz (former General Manager of Plant Lannach, Austria), Diba Ilunga (General Managers of Plant Ramos Arizpe, Mexico) and Bill Drury (former General Manager of Plant Changzhou and Tianjin, China) are interviewed to identify regional skills variances due to cultural and/or educational differences.

The answering options for the skills analysis are based on the O*NET Content Model[222]. Because a ranking of the entire O*NET Content model list of skills, abilities and knowledge would consume too much time of the interviews, this list is shortened. Similar and overlapping descriptions are summed to a single characteristic. The following steps have been undertaken to shorten the list of possible answers.

[222] A full list of the O*NET Content Model can be reviewed at http://www.onetcenter.org [22.02.2016]

1. **Find duplicates and similar descriptions**
   The first step was to find characteristics experts could not easily distinguish. As an example, the full list contained five different characteristics to describe mathematics skills. This included *“Mathematic Reasoning”*, *“Mathematics and Science”* (referred as knowledge), *“Basic and Advanced Mathematics”* (referred to level of education) and simply *“Mathematics”* in the category of basic skills. Thus, the interview contained only the answering option *“Mathematics”* and additionally asked the experts to explain their decision. By using this additional qualitative question, the experts are able to explain in which context they see the importance of their choice.
2. **Sum categories**
   In a second step, characteristics of overlapping categories and content are summarized. As an example, the category *“Complex Problem Solving Skills”* contains seven different types of skills. Therefore, only the main category has been used.
3. **Iterate**
   The last step was to iterate these steps till an appropriable number of characteristics are left. Taking again the example of *“Complex Problem Solving Skills”*, the O*NET Content Model also contained characteristics e.g. *“Problem Sensitivity”*, *“Analytical Thinking”*[223], and another category called *“Complex Problem Solving” in “Cross-Functional Skills”*. Thus, the final answer to choose was simply *“Problem Solving”* skills.

Characteristics related to unfamiliar disciplines e.g. Healthcare, Arts or History are not considered. To keep the list of characteristics manageable, all skills, abilities and knowledge descriptions are transferred into skills, which allowed the interviewee easier ranking. Before the interviews were conducted, this list has been discussed with the supervisors and adapted with their expertise input.

[223] The O*NET Content Model by http://www.onetcenter.org [05.02.2016] refers *„Analytical Thinking“* as needed if a *“job requires information and using logic to address work issues and problems”*.

The resulting list contained 15 skills to be ranked and can be reviewed in. If important skills were not on this by original list, they were asked to simply add the skills. Due to five added skills by the experts, the final list contained 20 characteristics to be rated.[224]

The interviews consist of ten semi-structured questions pertaining to three different topics. Interviews take approximately 45-60 minutes to conduct. Main content of the interviews is related to the case study project for the World Economic Forum – Global Agenda on the Future of Manufacturing. Thus, only seven questions are applicable for this thesis. The full questionnaire can be reviewed in Appendix 2.

3.2.2 Exploration of future requirements and training methods

Valuable input on future technologies used within manufacturing industry, and their impact on the future workforce in terms of tasks, skills needs and potential training methods with respect to regional differences has been provided by twelve international experts within in the automotive and manufacturing industry.

The experts are subdivided into three main categories due to their employment, location and knowledge. The first subdivision consists of four experts within European automotive supplier industry with fields of expertise in product development and manufacturing strategy. Another four experts have been interviewed within the San Francisco Bay Area. They are working in or with successful hardware start-ups and thus having knowledge in entrepreneurship and hands-on experience in product development and design thinking. Due to their very open minded approach, these experts are known to give out-of-the-box input. The third group represents Magna by three experts of Magna Powertrain and one of Magna Steyr Fahrzeugtechnik. All twelve interviewees are employed in global leading positions in operations related fields, C-level positions or higher.[225]

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[224] The full list can be reviewed in Appendix 5

[225] A list of all twelve interviewees is provided in Appendix 4. Due to confidential agreements, not all contact details are published.

The interviews consist of 13 semi-structured questions pertaining to three different topics. Each interview takes approximately about 45-60 minutes to conduct. In the first section, the main drivers for emerging technology trends get discussed and analyzed. It aims to build awareness about these concepts and identify how they affect the future work of human beings as it relates to manual manufacturing and engineering tasks.

The second section deals with the required know-how of manual manufacturing workers. Therefore, it is important to analyze the role of these employees in future production processes and discuss solutions of how to get machines and humans into balance in a social and economic way. In a next step the experts are asked to suggest the most important skills, abilities and knowledge for future industrial workforce. Therefore, the same procedure is used for this questionnaire as discussed in chapter 3.2.1. The experts get a list of 15 skills to rate the most important ones, free to add new items to the list if necessary. During this interview session, the experts added 2 skills. A detailed list of the available skills needs to rate is given in Appendix 5.

In some final questions regional differences between more, less and least developed countries in terms of technology trends and the requirements on production companies are identified. Therefore, regions are split according to UNFPA (2014).[226]

The full questionnaire can be reviewed in Appendix 1.

3.2.3 Designing a framework for future employee development

By the help of Magna Powertrain People Development and Training (PD&T) experts Eva Monsberger (Senior Manager PD&T and Recruiting) and Alexander Lahousen (Manager PD&T and Performance Management), a generic framework to design future employee development programs is developed.

In a first step, the output of all prior conducted expert interviews is analyzed. According to the suggestions of the interviewees, suitable training methods

[226] See Appendix 3.

are evaluated. The study focuses to identify emerging training methods with high applicability for future industrial workforce.

In a second step, literature about the identified methods gets reviewed. The results are discussed with Magna Powertrain PD&T experts and result in a generic framework to create suitable training methods, with respects to company specific needs.

4 Results

In this session, the results of the conducted expert interviews are discussed. Actual and predicted tasks, skills needs and training methods are compared in direct context to gain an easy overview of potential differences.

4.1 Tasks in digital manufacturing

When searching for future skills need and education methods, it is important to start with basic knowledge about the employees' tasks. Therefore, the actual tasks of employees get analyzed about their risk of computerization as to the study of Frey & Osborne (2013). Furthermore, the future tasks within digitized manufacturing get evaluated by analyzing the conducted expert interviews.

The next sub-chapters describe the findings of the job analysis and expert interviews regarding actual and future tasks in shop floor.

4.1.1 Actual tasks at shop-floor level

Out of O*NET SOC Taxonomy list of 974 occupations, 23 have been identified as jobs within the shop floor at Magna Powertrain Plant Lannach. The survey is applied on Operations functions, support functions are not considered.[227] These 23 occupations are committed to 1128 employees.[228] Figure 14 gives an overview to which extend the occupations are allocated within the plant.

[227] This includes departments like product engineering, finance, sales, marketing, human resources, legal, business development, etc.

[228] The survey is based on Magna Powertrain employment statistics of February 2016.

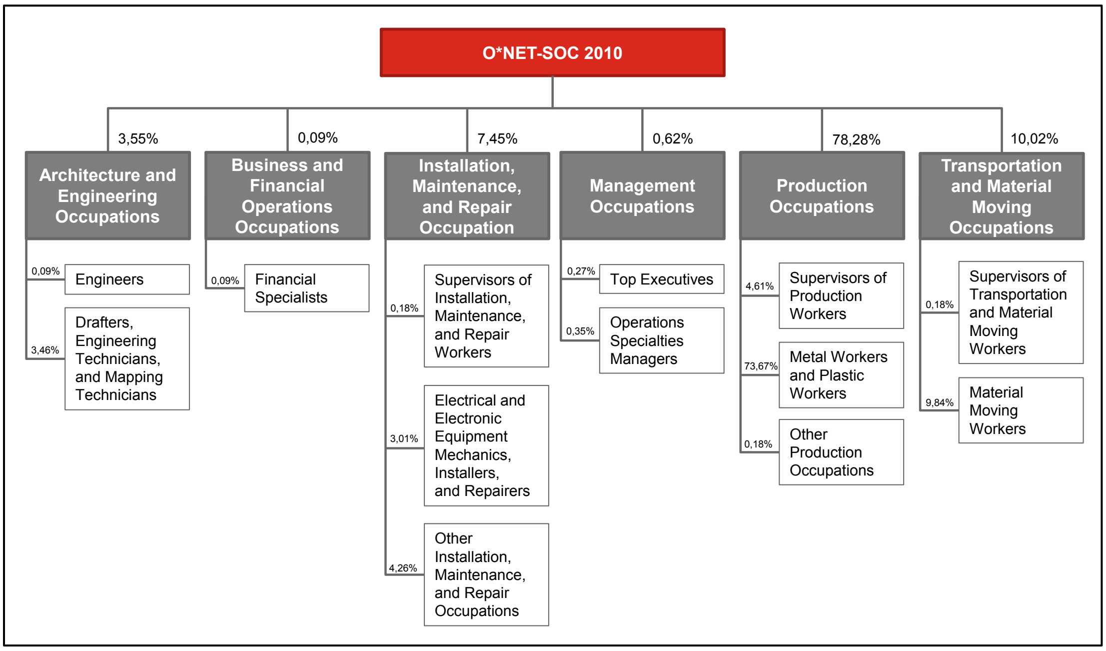

Figure 14: Estimation of occupations within Magna Powertrain Plant Lannach[229]

The highest number of occupations within a single minor group is given to 831 *"Metal Workers and Plastic Workers"* which equals 73,67% of all shop-floor employees. This group consists of 86 operators at the hardening shop, 73 operators at casting, 660 operators universally deployable, as well as eight tool makers and four tool grinders. With 9,84%, *"Material Moving Workers"* are the second largest minor group of employees. The group *"Other Installation, Maintenance, and Repair Occupations"* refers to the third largest group with 4,26%. The internal job description refers them to maintenance engineers with focus on mechanical components. *"Electrical and Electronic Equipment Mechanics, Installers, and Repairers"* are the counterpart of the prior named group, focusing on maintenance of electrical equipment. Together with their supervisors, the *"Installation, Maintenance, and Repair Occupation"* group refers to 7,45% of all employees. Appendix 6 provides an overview of all identified occupations according to the O*NET SOC Taxonomy and its' related risk level according to the study of Frey & Osborne (2013).

As a result, 15 of 23 occupations are at medium or low risk of getting substituted due to digitization, according to Frey & Osbornes' model. Due to

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[229] Illustration based on results of the conducted Job Analysis.

the high number of employees in *“Production Occupations”*, 943 employees are occupied in a job with high propability of getting substituted by digitization.[230] This equals a percentage of 83,60%, which dramatically exceeds the rating of 47% of U.S. labor market at high likelihood of substitution due to digitization, according to Frey & Osborne.[231]

The three jobs identified at highest risk are Operators at casting (propability p=0.95[232]), Auditors (p=0.94) and Machine Feeders (p=0.93). Operators working at hardening shop and those who are univerally applicable are rated as fourth higest risk (p=0.91).

The five identified occupations at highest risk get analyzed due to their most characterising work activities according to the O*NET Content Model.[233] Each occupation is described by 41 work activities, rated according their importance on the job. Having a view at the five highest rated work activities of the occupations, similarities are identifiable. Within the 25 possible work activities,[234] only 11 different work activities are identified within the five highest rated work activities. Three work activities are identified in four occupations, two of them *(“Handling and Moving Objects”* and *“Getting Information”*) are twice at highest rank. Three of the occupations are characterized by *“Controlling Machines and Processes”*, which is also highest ranked for one occupation. Work activities only found once in the top five ranking are *“Performing General Physical Activities”*, *“Monitor Processes, Materials, or Surroundings”*, *“Updating and Using Relevant Knowledge”*, *“Processing Information”* and *“Making Decisions and Solving Problems”*. The top 5 ranking of work activities can be reviewed in Table 2.

[230] A detailed list of all occupations and their risk of getting substituted by digitized equipment can be found in Appendix 7.

[231] Cf. Frey & Osborne (2013), p. 38

[232] The probability scale ranges from 0 to 1. A value between 0 and smaller 0.3 refers to low risk, 0.3 and lower than 0.7 medium risk and 0.7 to 1 refers to high risk according to Frey & Osborne (2013), pp. 37

[233] A comparison between work activities is expected to give more information about correlations between these occupations than analyzing O’NET task descriptions. Task descriptions are individually designed for each occupation and thus no correlations can be identified.

[234] Due to 5 options per 5 occupations, there are 25 different characteristics possible.

Table 2: Ranking of top five work activities[235]

	Operator Universally		Machine Feeders and Offbearers		Operator Casting		Operator Hardening		Auditors	
	Rate	Characteristic	Rate	Characteristic	Rate	Characteristic	Rate	Characteristic	Rate	Characteristic
1	85	Controlling Machines and Processes	76	Handling and Moving Objects	74	Handling and Moving Objects	77	Getting Information	94	Getting Information
2	73	Getting Information	73	Controlling Machines and Processes	68	Performing General Physical Activities	72	Controlling Machines and Processes	89	Evaluating Information to Determine Compliance with Standards
3	69	Inspecting Equipment, Structures, or Material	69	Monitor Processes, Materials, or Surroundings	66	Inspecting Equipment, Structures, or Material	70	Handling and Moving Objects	86	Communicating with Supervisors, Peers, or Subordinates
4	69	Handling and Moving Objects	69	Communicating with Supervisors, Peers, or Subordinates	64	Getting Information	68	Evaluating Information to Determine Compliance with Standards	85	Updating and Using Relevant Knowledge
5	68	Making Decisions and Solving Problems	67	Inspecting Equipment, Structures, or Material	63	Communicating with Supervisors, Peers, or Subordinates	67	Communicating with Supervisors, Peers, or Subordinates	84	Processing Information

4.1.2 Predictions on future tasks of employees at shop-floor level

The experts were asked to describe the differences of tasks performed by human and machine related to flexibility, quality and cost. In a next step, the experts are allowed to describe their general view about future work life. The following sub-chapters represent the view of the interviewed experts related on these topics.

Flexibility of human and machine

All of the experts do believe that actually human are the more flexible workforces. This is related to their creativity and their adaptability. They also think that this will stay in future, but the tasks will change. Employees will become the creative heads leading the machines. Machines actually are good in performing given tasks. Actual robots are getting developed to perform just one specific task in perfection at low costs and easy handling. In future, these tasks will be put together to a bigger system, which can perform more tasks, and easily learn new tasks to be performed in perfection. This development will not happen from one day to the other. It is easier if the

[235] Cf. http://www.onetcenter.org [22.02.2016]

machining for a certain process is built up of modular parts, so specific modules can change when needed and no extra machine setup and training is needed. And even then, human will be the ones who teach the robots tasks.

Automated production will give you the most consistent products, and machines will be able to perform tasks, a human simply can't do because of physical reasons (e.g. carrying heavy loads or assembling precise parts) All tasks where creativity and adaptability, as well as dexterity is needed, the human will stay the most flexible workforce even in future according to the interviewees.

If we think about the most flexible way to produce in an overall look, it's not possible to say whether this is possible by human or machine. It's the combination, the system that leads the production to be flexible and agile enough to react on the volatility of markets. It's about reducing bottlenecks and making the whole system, consisting of hardware, software and communication/interfaces, flexible. It's about using benefits of various components to build a flexible system to master complex situations. To make quick decision, you must know about market situation, production capacities, production technologies, etc. This is seems difficult to achieve without interconnected machines, and won't work in sense of big data if sending everything to a single person who makes the decision. A decentralize controlled combination of advanced analytics and human expertise will be key to reduce and handle complexity.

Quality and cost of human and machine production

It is clear to the experts that digitized equipment (especially robots) has some dramatic advantages against human labor. This is especially the quality they produce. Machines are able to produce tolerances human simply can't visualize. Expert 2 mentioned the "iPhone screws" which are assembled in the newer generations. These tiny screws, which can be easily lost, must be inserted in a certain position, in every single product, even if the part is so small that nobody would see it. Because this work was simple not possible for human beings, special robotics had to be built for the assembly process.

If service and maintenance is done right, machines can performed their tasks 24/7 without a single error or a break. This saves much time and money plus increasing throughput dramatically. Today, the installation cost of digitized equipment is too high, but computer prizes usually fall while labor cost increase. The occurring gap can be seen as another benefit of using machines.

Tasks of human and machine in manufacturing

When it comes to the question which tasks will be performed by human, the experts are concurring very strongly on three kinds of tasks:

1. **Supervising machines and digitized equipment**
   Human will be responsible for keeping production lines running. They have to observe and control the processes and the machines. In case of occurrences, they have to quickly react and find solutions for the problems. Additionally, the will be responsible to continuously improve the processes they are working on.
2. **Tasks requiring human specific skills**
   The human body is a very complex and unique product. Especially the ability to feel things is what makes human distinct. This includes especially senses like e.g. visioning, finger dexterity, hearing or smelling. Sensors are able to reproduce these kind of skills, but even in future the experts believe it will be difficult to implement such a high number of sensors with the same accuracy and complexity as a human body can process. Additionally, human have skills that are very difficult to turn into digits, which is experience and gut feeling.
3. **Tasks requiring non-routine cognitive skills and soft skills**
   Another kind of tasks that can’t be easily adopted by machines is everything that aims to create something new. Human are the creative ones, able to design new things, no matter if product or process. In shop floor, this affects mainly the problem solving and decision making part of employees.

4.1.3 Summary future tasks

Having a look at the actual tasks of employees in jobs at high risk of getting substituted by digitization strongly correlates with past developments. Higher rated work activities are comparable to routine manual, non-routine manual cognitive tasks. They can be described as tasks that can be accomplished by following a set of deductive or inductive rules. According to the study of Autor, Levy & Murnane (2003), jobs of these categories have already been reduced and tend to further decline. Additionally, work activities rarely identified for these occupations are representatives of non-routine analytical and cognitive tasks, which are predicted to be more important in future.[236]

High rated work activities of occupations at high risk of getting substituted due to digitization are exactly what Industry 4.0 enabling technologies aim for. Comparing to literature, following statements about the three highest rated work activities can be set:

1. **"Handling and Moving Objects"**
   This work activity refers to the usage of hands and arms in handling, installing, positioning and moving materials and manipulating things. [237] These kinds of tasks are often referred as being supported or completely substituted by (collaborative) robotics.[238] Human Robot Collaboration (HRC) is already widely used. Especially in automotive industry, HRC is widely used e.g. in body shop, which is often up to 95% automated.[239] According to expert 9, this is possible because human are not able to fulfill this work in terms of physical reasons. In assembly lines, this is not possible because of the parts different tolerances. According to him, human dexterity is crucial to fit parts together because as long as they are produced with tolerances. Meanwhile, robots support human on these tasks and additionally take over non-critical task according to him. A study of MIT shows that autonomous robots are already able to outperform a human worker in part or all of the task allocation.[240] Also experts claim that there is no

[236] Cf. Autor, Levy, & Murnane (2003), p. 1286; Levy, & Murnane (2007), pp. 14; Levy & Murnane (2013), pp. 16

[237] Definition by http://www.onetcenter.org [05.02.2016]

[238] Cf. Gombolay, et al. (2014), p. 293; Miremadi, et al. (2015), p. 3; Levy & Murnane (2013), p. 17

[239] Cf. Bundy, Möller, & Wee (2015), p. 3

[240] Cf. Gombolay, et al. (2014), p. 293

way human labor is competitive to robots in routine manual tasks, especially at times of sinking robots and increasing labor costs.[241]

2. **"Getting Information"**
   O*NET describes this work activity as *"Observing, receiving, and otherwise obtaining information from all relevant sources."* [242] This activity describes what the combination of the Internet of Things (IoT), Cyber Physical Systems (CPS) and advanced analytics is often referred to. All relevant sources are CPS, which are connected via the IoT.[243] Advanced analytics continuously analyze the information received to identify initial patterns, data correlation and inter-linkages within a network of machines, tools, material, etc.[244] In this case, the protagonist that is performing the work activity *"Getting Information"* is another CPS. It doesn't matter if the obtaining CPS is an intelligent and autonomously acting robot or a wearable that is controlled by human. According to experts and literature, this is not a task human should do because the effort to manually gather information in a digitized environment is waste.[245]
3. **"Controlling Machines and Processes"**
   By definition of O*NET Content Model, *"Controlling Machines and Processes"* is defined as *"Using either control mechanisms or direct physical activity to operate machines or processes (not including computers or vehicles)"* [246] Experts believe that in future, employees will control a higher number of machines on remote. Therefore, they use computers and the network of the Industrial Internet. Literature also suggests that future shop floor workforce may be able to control their machines at home.[247] Thus, it is predictable that human will control machines via digitized equipment and furthermore physical controlling and other mechanisms will fall away.

[241] Cf. Tilley (2015), p. 3

[242] Cf. http://www.onetcenter.org [05.02.2016]

[243] Cf. Geisberger & Broy (2012), p. 22; Majstorovic, et al. (2015), p. 10; Sihn (2015), p. 18; World Economic Forum (2015), pp. 3

[244] Cf. Auschitzky, Hammer, & Rajagopaul (2014), pp. 2

[245] Cf. Behrendt, et al. (2016), pp. 2

[246] Cf. http://www.onetcenter.org [05.02.2016]

[247] Cf. Blanchet, et al. (2014), p. 8

The experts agree on the question how much tasks human will perform in future. To them it is absolutely clear, that the number of manual tasks performed by human will decrease. And all of them are sure that this direction won’t change anymore. Experts see the necessity of human employees in the shop floor and thus the number of employees itself not necessarily decreasing. They see a decreasing ratio of human and machines in the shop floor, but just because of an increasing machinery park. In future, a single employee will be able to handle more than 10 machines/robots at the same time, on remote.

Literature often refers to a dramatic decrease in available jobs as Table 3 shows. Still, the interviewed experts believe the number of employees will fall only slightly or even remain the same. They see changes in the tasks performed by the employees. Additionally, they emphasize that this implies also changes of employees’ skills needs and thus suitable education and training programs are necessary, which is further discussed in the next chapters.

Table 3: Summary of studies according to job losses due to digitization[248]

Author	Core statement	Time horizon
FREY & OSBORNE (2013)	47% of U.S. labor at high risk of being substituted by machine.	2030
BRZESKI & BURK (2015)	59% of German labor at high risk of being substituted by machine.	2030
BONIN, GREGORY & ZIERAHN (2015)	9% of U.S. / 12% of German labor at high risk of being substituted by machine.	2030
WOLTER ET AL. (2015)	Approximately 60.000 jobs in Germany will be reduced – about 420.000 jobs will get reduced mainly in manufacturing, 360.000 will be created in other disciplines.	2030
RÜSSMANN ET AL. (2015)	Approximately 350.000 jobs in Germany will be created– about 610.000 jobs will get reduced mainly in manufacturing, 960.000 will be created in other disciplines.	2025

4.2 Skills needs to handle future equipment

Within the following sub-chapter, the actual skills level of manufacturing employees and their in future needed skills level gets analyzed. The actual skills level is gathered by the O*NET Content Model database and experts interviews with regional General Managers.

In future needed skills level is predicted to strongly depend on future technologies, implied organizational changes and related future tasks of employees. Therefore, the experts within the future requirements interview session where asked to give a thought about the future skills needs of manufacturing and engineering employees, based on their prior answers.

Additionally, actual research activities and programs have been screened to gain a broad view about future skills requirements.

[248] Illustration based on cited authors.

4.2.1 Actual skills level of employees

When designing a plan to reach a certain goal in the future, it is crucial to know the starting point very well. As a conclusion, to define methods in teaching employees future requirements, it is also important to identify what they already know. Therefore, general occupations data provided by the O*Net database gets analyzed and additionally compared to Magna Powertrain specific jobs.

Skills of Top 3 Occupations within Magna Powertrain Lannach Plant

The conducted Job Analysis identified 23 occupations with 1128 employees at the shop floor of Magna Powertrain Plant Lannach. To get an overview of the actual skills level of employees, the three biggest groups of employees get analyzed. These three include *“Operators Universally”*, *“Distributors & Material Handlers”* and *“Operator Hardening”*. As the three types of operators[249] are described by similar characteristics, only “Operators Universally” is considered. Additionally, the needed skills, abilities and knowledge of *“Distributors & Material Handlers”* and “Maintenance Mechanics”[250] are considered. Appendix 6 reviews the complete list of occupations within the shop floor of Magna Powertrain Plant Lannach. The O*NET Content Model rates each skills, ability and knowledge of the specific occupation within a range of 0 to 100, which is the maximum score and thus the most important. Table 4 shows an overview of the five most important skills, abilities and knowledge within the 3 biggest groups of occupations identified.

[249] *„Operator Casting“* is the third form, representing the fourth biggest occupational group.

[250] *„Maintenance Mechanics“* represent the fifth biggest group of occupations.

Table 4: Skills, abilities and knowledge of the 3 biggest occupational groups[251]

		Operator Universally		Distributors & Material Handlers		Maintenance Mechanics	
		Rate	Characteristic	Rate	Characteristic	Rate	Characteristic
Skills	1	72	Operation Monitoring	47	Critical Thinking	78	Equipment Maintenance
	2	60	Quality Control Analysis	47	Coordination	78	Repairing
	3	56	Operation and Control	47	Operation and Control	75	Operation Monitoring
	4	53	Critical Thinking	44	Reading Comprehension	72	Troubleshooting
	5	53	Monitoring	44	Active Listening	66	Operation and Control
Abilities	1	72	Control Precision	69	Static Strength	72	Arm-Hand Steadiness
	2	66	Problem Sensitivity	63	Multilimb Coordination	72	Manual Dexterity
	3	66	Arm-Hand Steadiness	63	Trunk Strength	69	Finger Dexterity
	4	66	Manual Dexterity	56	Control Precision	69	Control Precision
	5	63	Near Vision	53	Oral Comprehension	69	Multilimb Coordination
Knowledge	1	73	Mechanical	45	English Language	90	Mechanical
	2	69	Mathematics	40	Mathematics	67	Engineering and Technology
	3	63	Production and Processing	36	Transportation	63	Production and Processing
	4	54	Design	33	Mechanical	61	Mathematics
	5	51	Engineering and Technology	31	Production and Processing	61	English Language

In general, these three types of occupations slightly differ in terms of characteristics but also importance of the difficult skills. In a next step, each category is discussed.

1. **Skills**
   In terms of needed skills, all occupations overlap at some point. All three require skills in *"Operation and Control"*, but on a different importance, ranging from 47 for *"Distribution & Material Handlers"* to 66 for *"Maintenance Mechanics"*. *"Maintenance Mechanics"* strongly require occupation specific skills such as *"Equipment Maintenance"* and *"Repairing"* both rated 78. Against that, *"Operator Universally"* require *"Operation Monitoring"* skills (72) and *"Quality Control Analysis"* skills (60). Additionally, two of the three occupations highly require *"Operation Monitoring"* skills and *"Critical Thinking"*. It is noticeable that skills rating of all five highest ranked skills of *"Distribution & Material Handlers"* don't exceed 50, which is only half of the available score.
2. **Abilities**
   All three occupations highly require the ability for *"Control Precision"*. Also *"Manual Dexterity"*, *"Arm-Hand Steadiness"* and *"Multilimb Coordination"* is important for two of the three occupations. In this

[251] Illustration based on http://www.onetcenter.org [05.02.2016] and Magna Powertrain experts

category all highest rated characteristics are rated at similar importance.

3. **Knowledge**

   The required knowledge differs more between the three occupations than the first two categories. Each occupation requires different top knowledge at a highly varying importance. *“Operator Universally”* has high needs for *“Mechanical”*, *“Mathematics”*, and *“Production and Processing”* with an importance ranging from 63 to 73. *“Distribution & Material Handlers”* require *“Transportation”* knowledge only at an importance of 36, surpassed by *“Mathematics”* (40) and *“English”* (45) knowledge. *“Maintenance Mechanics”* clearly requires “Mechanical” knowledge (90) to successfully fulfill the jobs. This is followed by knowledge about *“Engineering and Technology”* (67) and *“Production and Processing”* (63).

Highest required skills, abilities and knowledge

In a next step, the highest required skills, abilities and knowledge get evaluated. Therefore, the importance of the highest ranked characteristics of the biggest five occupational groups get multiplied with the number of employees of each category:

$$Importance\ I = Rank\ R * \#\ of\ employees\ N$$

As a result, the most important skills due to this evaluation are:

1. Operation Monitoring
2. Operation and Control
3. Quality Control Analysis

The highest required abilities are:

1. Control Precision
2. Arm-Hand Steadiness
3. Manual Dexterity

The most important knowledge is referred to

1. Mechanical
2. Production and Processing
3. Mathematics

The full result can be reviewed in Table 5.

Table 5: Importance of skills, abilities and knowledge of the three biggest occupational groups[252]

SKILLS	RATING	ABILITIES	RATING	KNOWLEDGE	RATING
Operation Monitoring	60756	Control Precision	61488	Mechanical	62697
Operation and Control	54912	Arm-Hand Steadiness	56895	Production and Processing	56370
Quality Control Analysis	44416	Manual Dexterity	56457	Mathematics	55568
Critical Thinking	44144	Problem Sensitivity	48159	Engineering and Technology	38232
Monitoring	39360	Near Vision	41580	Design	35640
Active Listening	13179	Multilimb Coordination	19761	English Language	7300
Reading Comprehension	9052	Static Strength	12612	Public Safety and Security	4898
Coordination	5076	Trunk Strength	6804	Transportation	3888
Equipment Maintenance	3120	Oral Comprehension	5724	Computers and Electronics	3212
Repairing	3120	Selective Attention	4599	Chemistry	3139
Troubleshooting	2880	Finger Dexterity	2760		

Due to the high number of operator occupations, the result of the analysis is questionable. Appendix 8 contains a detailed view of the rating regarding number of employees and individual skills, abilities and knowledge importance.

Regional differences by the expert interviews

To identify regional differences of the manufacturing employee's skills level, actual and former General Managers of plants in Austria, Mexico and China have been interviewed.

They were asked to rank a list of skills, abilities and knowledge according to the actual level of their employees.[253] Five skills have been picked and rated by 1 to 5, where 1 was the highest score. Additionally, the options are categorized into “soft” and “hard” skills. Table 6 shows the top rated skills of

[252] Illustration based on http://www.onetcenter.org [05.02.2016] and Magna Powertrain experts

[253] The full list for skills rating can be reviewed in Appendix 5.

manufacturing employees, according to their location. Also the skills of engineering workforce were asked to have an additional comparison.

Table 6: Top skills of manufacturing and engineering occupations[254]

Top Skills in Manufacturing			
Rank	**Austria**	**Mexico**	**China**
1	Information and Communication Technologies	Self -motivation	Social behavior
2	Math	Operational discipline	Self -motivation
3	Physics	Readiness to learn / openness to change	Information and Communication Technologies
4	Electrical wiring	Basic Science	Processing technologies
5	Self -motivation	Problem solving	Organizational planning
Top Skills in Engineering			
Rank	**Austria**	**Mexico**	**China**
1	Mechanics	Self -motivation	Social behavior
2	Electrical wiring	Basic Science	Math
3	Information and Communication Technologies	Organizational planning	Physics
4	Physics	Problem solving	Metallurgy
5	Metallurgy	Decision making	Self -motivation

According to the interviewees, Austrian manufacturing workforce is more trained with soft skills than the engineering employees, which is also true for the Chinese manufacturing workforce. The Mexican's "soft/hard" skills balance stays the same within manufacturing and engineering, even if the top skills vary.

[254] Illustration based on expert interviews

The interviewees assign these differences to the regional school systems and general cultural differences. To them, it is crucial that country specific educational and cultural differences are considered within a global organization. This includes allocation and execution of tasks in daily work live but also the way employees are engaged to training. Thus, general conception of training models, the content transferred, didactical concepts used and motivation to attend training must be individually designed.

4.2.2 Future skills needs of employees

The questionnaire for future skills needs evaluation is based on the interview guideline for regional General Managers. The original list of characteristics to be rated again contained 15 skills and got added with two additional answer possibilities by the experts. The full list of 17 answer options can be reviewed in Appendix 5.

The experts were also asked to choose the 5 most important skills they are expecting within manufacturing industry in year 2035 and beyond. They were asked to rate the given skills from 1 (most important) to 5. Not all of the experts were able to exactly choose 5 skills, or to rank them from 1-5. The experts were also allowed to add additional skills they suggest to be important. Those got added to the questionnaire and used within following interviews. To make the result more visible in overall organizational context, the interviewees where also asked to rate the skills crucial for engineering by using the same list. An overview of the rated skills for manufacturing and engineering is given within Figure 15 and Figure 16.

Figure 15: Required Skills level in manufacturing[255]

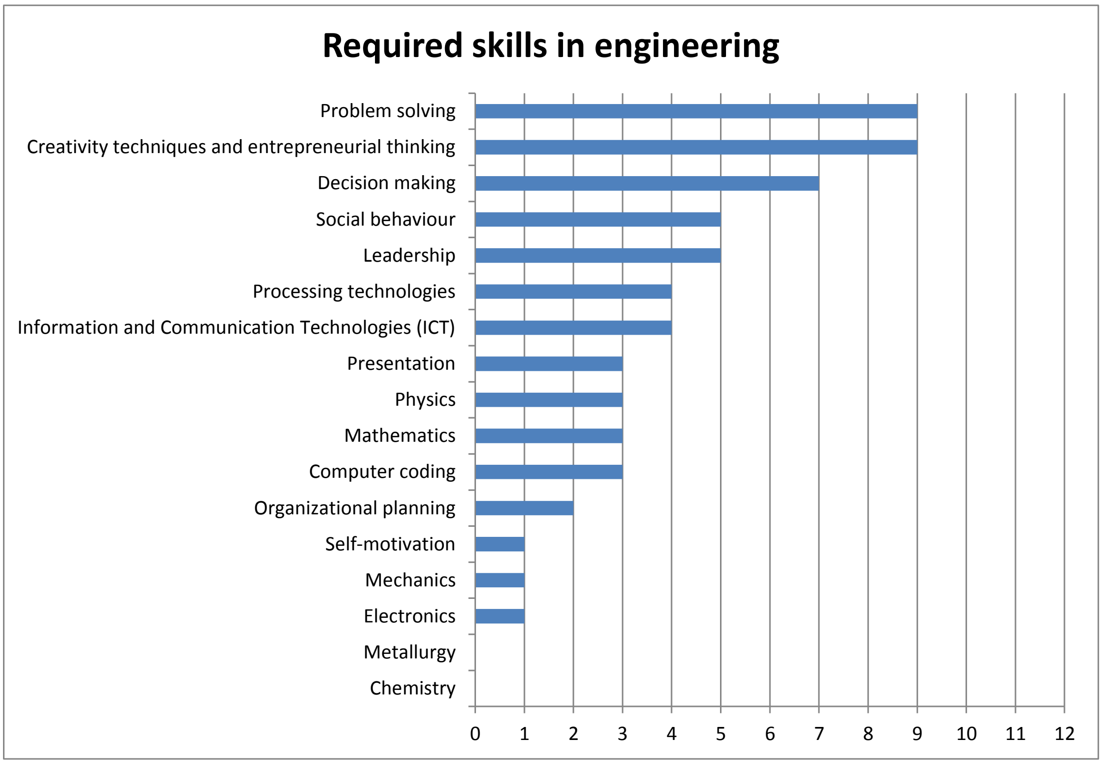

Figure 16: Required Skills level in engineering[256]

[255] Illustration based on expert interviews

[256] Illustration based on expert interviews

According to the experts, problem-solving skills will be the most important to both manufacturing and engineering employees. In manufacturing, all experts took problem solving. For engineering they rated creativity techniques and entrepreneurial thinking together with problem solving to the most important skills. Decision-making and leadership skills are also within the top five rated skills needs of both. To complete the top five skills needs, the two categories differ slightly. In manufacturing, experts expect knowledge about manufacturing technologies as one of the top priorities, whereas engineers should be well trained in social behavior.

Skills like chemistry, electronics or metallurgy are expected to be least important to the future workforce. Often these kinds of skills are seen as kind of basics to everybody. Some experts claimed that a veritable suggestion couldn’t be made as most of the skills options strongly depend on the product, the production strategy, and the specific job itself. Therefore, STEM (Science, Technology, Engineering and Mathematics) fields are refer to basic knowledge for future workforce.

Additionally, the skills needs options have been divided into soft and hard skills, as it was within the analysis of actual skills level. The analysis of the future skills should give an overview how the ratio of soft and hard skills will evolve within the next decades. Comparing the results with the estimation of actual skills level, a clear movement into the higher importance of soft skills. As to the general managers in prior discussed interviews, actual amount of soft skills of manufacturing employees is about 53%. According to these experts, about 70% of all skills will be related to soft skills, independent from manufacturing or engineering part.

4.2.3 Summary future skills needs

Analyzing the outcome of the expert interviews and combining them with suggestions of actual literature leads to four categories of skills sets identified as key competencies for future manufacturing employees. The following sub-chapters describe the four identified categories and put them together to a generic concept.

STEM – Science, Technology, Engineering and Mathematics

According to experts, a solid foundation in STEM skills can be seen as the basement for a successful manufacturing career. High interest and basic understanding in Science, Technology and Engineering fields enables further training in complex manufacturing techniques. High-level mathematic skills are necessary to deal with calculation tasks ranging from e.g. machine setups to production planning activities. Advanced STEM skills enable employees to invent and operate new manufacturing technologies and products.

Literature and experts refer low enrollment and less attention in STEM education are often referred as strong barriers for manufacturing companies finding adequate personnel. According to Morrison et al. (2011), 2 of 5 highest skills deficits are reported in basic technical training and adequate math skills.[257] Therefore, the first initiatives to prevent this lack of STEM knowledge are already launched, such as e.g. the National Science and Technology Council launched a 5 years strategic plan for STEM education in US.[258]

MES (Mechanics, Electronics and Software) and Manufacturing Technique

To keep production and assembly lines running, workers need to deal with more cross-functional challenges than ever. Mechatronics (which combines knowledge in the fields of Mechanics and Electronics) will still play an important role to handle and maintain mechanical and electrical components within machines. Additionally, basic knowledge in algorithms and coding will be necessary to collaborate with digital equipment.[259] Thus, employees will need to program and teach advanced machinery, to uphold connection and communication within the network, and to analyze and solve unpredicted problems.[260] Also experts believe programming skills or skills in teaching

[257] Cf. Morrison, et al. (2011), p. 8

[258] Cf. National Science and Technology Council (2013), p. 2

[259] Cf. Kärcher (2015), p. 55; Rüßmann, et al. (2015), pp. 8

[260] Cf. Luksha & Lyavina (2014), p. 112

digital equipment will get increasingly important. Expert 3 predicts even fruit pickers will have to deal with programming in future. In case of operating errors, breakdowns or other unpredictable events, manufacturing workforce (operators, machine setters, etc.) has to be aware of their possibilities and react intermediately. Thus, a balanced foundation of skills related to Mechanics, Electronics and Software is needed.

New technologies will be developed and implemented into existing processes. Workers need to be open to these technologies and being capable of working with them. As the upcoming generation grows up with smartphones, tablets and all kind of implemented apps, they are already used to digital equipment and Information and Communication Technologies (ICT). Most of the interviewed experts believe older generation will have more problems with using these technologies and therefore need intensive training in manufacturing techniques, including the machines, tools and material they are working with. They report about their own and their employees' difficulties when they needed to learn how to use specific computer tools for job. All of the interviewees with children are enthusiastic about the ICT skills of their kids at youngest ages when using a laptop or tablet computer.

Against that, literature does not necessarily confirm older generations as being more resistant to change in general than younger people. Mature workers are just blamed more often for conflict about change. Some studies also suggest mature-aged employees react more readily on change and are keen of being part of a change process.[261]

Soft skills

The biggest differences between human labor and machines are presented by social capabilities, because they are difficult to transfer into bits. Skills like e.g. sense-making, social intelligence, design mindset or trans disciplinary are just some examples that enable critical tasks of human.[262] These skills are exactly what makes human unique compared to digital production

[261] Cf. Vasconcelos (2015), p. 355

[262] Cf. Davies, Fidler, & Gorbis (2011), p. 13

equipment according to the experts. They enable humans to solve novel problems and to make fast decisions based on insufficient and new information. Creative and entrepreneurial thinking will foster fast innovation, increasingly important to implement the next big leaps one step faster than competition.

Additionally, employees need to be open for change and adapt quickly to guarantee flexibility at all hierarchical levels.[263] As an example, problem solving is already referred as the most serious skills deficiency in U.S. manufacturing, followed by basic technical training, employability skills and inadequate math skills.[264] Thus, adequate training has to be one of the top priorities of all entities involved to create a sustainable manufacturing environment.

Overall skills concept

Putting the prior in literature and expert interviews discussed skills, abilities and knowledge into a generic concept, a picture of future needed skills evolves.

Experts and literature often call STEM skills *“basic knowledge”* or referred it as a *“solid foundation”* to understand engineering and manufacturing related topics. They refer soft skills as the specific skills that make human singular. Experts refer them as the most important skills for future. This exceeds the importance of manufacturing technologies, techniques or processes knowledge and about advanced skills in mechanics, electronics and software.

On a generic view, STEM skills can be seen as the *“basement”* for sustainable technical knowledge generations. Soft Skills are at the top of all skills to be developed and thus can be seen as the “rooftop”. Knowledge in mechanics, electronics and software as well as basic and advanced manufacturing technologies are the two pillars, creating a generic framework

[263] Cf. Lorenz, et al. (2015), p. 15

[264] Cf. Morrison, et al. (2011), p. 8

for interdisciplinary competence in product, process and technology related topics to handle digitized production equipment.

According to experts, adapting these skills on company specific requirements e.g. processes, technologies or products, individual designed employee development methods is necessary. Figure 17 illustrates the findings of expert interviews and literature research in a generic framework.

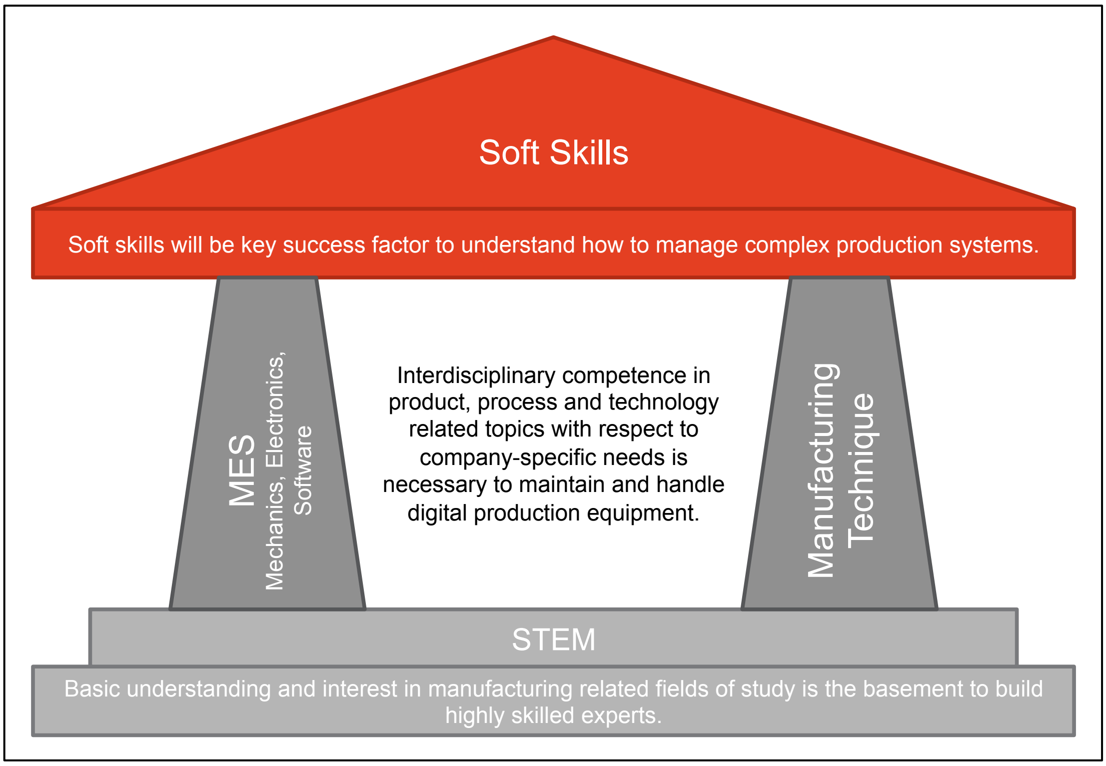

Figure 17: The Skills Temple[265]

4.3 Employee development in digitized manufacturing

Within the following sub-chapters, emerging training methods get analyzed and a framework to design future trainings is developed.

In a first step, international manufacturing and automotive experts are asked to suggest their view in how future employee development should look like. As an outcome, three actually emerging education concepts can be identified

[265] Illustration based on analysis of literature review and expert interviews.

at high potential for future training and get further investigated within the sub-chapters.

In a second step, the identified methods are discussed with Magna Powertrain People Development and Training (PD&T) experts to design a generic framework for designing adequate employee trainings with respect to company specific requirements.

4.3.1 Future training needs

After analyzing *what* the employees have to be trained, also the question about *how* to teach the required skills set must be asked. Within the following sub-chapters, two training scenarios can be distinguished:

1. **Student development**
   Education programs e.g. school, apprenticeship or university, are briefly analyzed due to their future potential are analyzed.
2. **Employee development**
   In this section, experts are asked about potential employee development methods. These include in-house employee development programs and cooperation with external training providers including academia and private training providers.

Student development

In terms of education, the experts totally agree on one point, it’s the mixture of practical and theoretical knowledge that counts. It is extremely important to them, that students (school and university) gain more practical experience. They have to know what’s going on in the shop floor and how work is done. This experience is essential to understand the tasks performed to produce their own goods. But also manual workers have to be educated in theoretical skills and soft skills as well.

The interesting thing is, that the interviewees prefer very different education methods for teaching the future workforces in manufacturing and engineering tasks.

It starts within primary and secondary education where (especially European experts) claim a lack of STEM education. They see kids getting less attracted to technical disciplines less used to STEM fields. It is not necessary to extensively teach the use of digital equipment as they grow up with these technologies, but the interest in building things must be aroused again. Additionally, experts claim that schools system push young students into certain directions and produces kids having all the same skills. They refer it as a lack of individual education and thus claim high needs to build on students' specific interests and knowledge, which could be tackled by individual and *self-paced learning*.

An advanced education system highly preferred by the interviewed experts is the apprenticeship model. This includes not just the European experts, also U.S. interviewees know this system and envy European industries therefore. They count it as a good ratio between theoretical and practical input. Expert 2 believes that this model should be also applied to educate engineers and refers "young engineers can be best prepared for future challenges by other engineers". A problem can be seen in the content of this model. According to the experts, apprentices often gain insufficient theoretical input. They gain less interdisciplinary input and lack of soft skills such as creativity or problem solving skills can be identified.

The interviewed experts refer universities, independent of their region, as very good systems to educate engineers, but with far to less practical input. Students have to understand the work at shop floor better and thus *hands-on education* is important. Therefore, experts suggest industry internships and laboratories that simulate shop floor environment (in literature often called *learning factories*) as highly promising. Expert 1 highly criticizes engineering graduates with less practical know-how. In his opinion *"it's crazy to call them engineers when they are not able to fix their cars if it breaks down."*

Experts also believe that new and innovate education systems have to be developed. Some of them see high potential in the use of digital technologies and the internet. Expert 4 believes that MOOCs (he refers the KHAN Academy as an example) are powerful instruments to teach various skills (math, science, computer coding, art economics, etc.) by using thousands of interactive exercises, role-plays, etc. Students can choose on their own what skills they want to develop, where to learn, how fast to learn it and directly apply it in practice. This is what literature refers as *self-paced learning*.[266]

As an outcome, the experts refer it as most important to get kids interested again in technology, to take care about their individual interests and to provide them a well-balanced mixture of theoretical and practical knowledge.

Employee development

All experts agree on the importance of *lifelong learning*. Training should be offered to every employee, regardless if blue-collar of white-collar worker. It is important also shop-floor employees get access to training, as they are predicted to become knowledge workers. This implies also that employees must be open for change. As an example, expert 7 reveals the difficulties in teaching older employees how to work with a computer. In his point of view the employees where not willing to change their business life because they didn't see the benefits and didn't have fun in working with those technologies and thus weren't able to learn it for a long time. Therefore, it is crucial that employees are open to change and accept the necessity of learning in order to survive in digitized manufacturing environment.

Suggested training methods of the interviewees range from very conservative approaches to highly futuristic ones. One development method mentioned was a three-weeks training academy. This training method gives learners to chance to learn their job directly at the machines, supported by any kind of mentor. This approach mainly transfers *hands-on experience* and is already a common approach in employee development. Expert 5 believes such programs will stay successful in future but content must be adapted on digitized manufacturing.

On the other hand side, expert 2 believes the highest challenge lies in the soft skills training, because workers gain practical skills on the job anyhow. Therefore, it is also conceivable that employees attend regular courses at universities or schools. Expert 4 believes *individual* and *self-paced learning* is also applicable for employee development and refers the model of KHAN

[266] Cf. Markowitsch, Messerer, & Prokopp (2004), p. 39

Academy as highly promising. There is high potential to this training methods as employees are able to choose their own topics, attend the courses they are interested in and are able to attend when and from where ever they want.

In general, experts see a very strong trend in combining practical and theoretical knowledge in both, manufacturing and engineering tasks. They don't see the big differences between these jobs anymore because they will all live from the creativity and adaptability of human. This is why collaborations between public and private sector, universities and companies are very important for future work tasks. Experts do believe that by now universities are very good institutions to teach theoretical knowledge but not practical knowledge. Therefore, laboratories *simulating real life situation* are necessary. Expert 2 believes that another big problem of industry is the permission of making failures. Of course, already small failures can harm business success dramatically, but in his opinion, people learn from failing. Therefore, creating an environment that allows failures should be created for employee development. Practical knowledge can easily be developed in industry by performing manual tasks. This often implies a lack of soft skills when it comes to problem solving and decision-making tasks. A good combination of both is what makes future industrial workforce competitive.

Implied didactical concepts

The interviewed experts indirectly referred to a high number of different didactical concepts. These didactical concepts are considered when thinking about future training methods.

1. They claim a high-need in **hands-on experience** at shop floor or simulation this environment. This is usually featured by **experiential learning** and **action-oriented learning** and often implies **problem-oriented** and **project-based learning** methods.
2. By describing MOOCs to individually choose the topic to learn and decide time and place where to learn, experts indirectly describe the concept of **self-organized learning**.
3. Getting real life situation and examples into learning environment refers to **project-oriented learning** and **case based learning**.

4.3.2 Suggested future training methods and education cooperation

Based on the answers of experts and the reviewed literature, three training methods for academia but also business level have been identified with high potential to fulfill future requirements.

All experts referred practical experience as biggest lack of actual education and thus *hands-on learning* is needed. Therefore, the next chapters handle the use of Fab Labs and Learning Factories in academia, but more important in cooperation with industry to support employee development.[267]

Expert 4 additionally highlighted the KHAN Academy as high potential trainings method for future students and employees, which can be seen as a pioneer of MOOCs providers.

The following sub-chapters discuss basic characteristics and potential implementation strategies for MOOCs, Learning Factories and Fab Labs into employee development.

MOOCs

Massive Open Online Courses, or MOOCs, are examples for using digital technologies in education. The basic idea behind MOOCs is anybody should have the chance to gain knowledge regardless of demographic, economic or geographical constraints.[268]

The concept of MOOCs

Students are able to create self-organized and self-paced learning environments. They can spend as much time as needed on the topic and also check their gained knowledge via tests. When Anant Agarwal revealed the data about one of his MITx courses (MIT's online education initiative), he found out students where extra motivated. They started their homework often

[267] Cf. Eberhard, et al. (2015), p. 2; Gershenfeld (2005), p. 185; Mostert-Van der Sar, et al. (2013); p. 631; Tisch, et al. (2013), p. 583

[268] Cf. Yuan & Powell (2013), p. 6

before watching the lectures and thus got highly motivated to really understand the content to solve the specific challenges. [269]

There are also some economic benefits about MOOCs as they enable low-cost replication of the best teachers, content and methods. There are also predictions that classrooms will flip, which means students listen to the lectures from their home base and switch the homework exercises, problem sets and writing assignments in school where peers, teachers and coaches can help.[270]

As an example, in 2011, the artificial intelligence expert and driving force behind Google Self-Driving Car Project Sebastian Thrun announced an AI introduction online course available for free with just a single email to his Stanford students. As a result, over 160.000 students from all over the world registered to the course and tens of thousands completed all exercises and exams. Surprisingly, the top Stanford students got outperformed. The best Stanford student was only the 411th best among all online students.[271]

Currently, many universities, online platforms and companies offer MOOCs. Often referred as leaders in this field are *MITx*, *edX*, *Coursera*, *Udemy* and *Udacity*.[272]

Types of MOOCs

In general, we derive between two distinct pedagogical directions of MOOCs. The *cMOOCs* model (connectivist MOOC) is built on the principles of connectivism, which emphasizes creativity, autonomy, diversity and interactivity. Social learning network environments are important factors within cMOOC.[273]

[269] Cf. Brynjolfsson & McAfee (2014), pp. 199

[270] Cf. Brynjolfsson & McAfee (2014), p. 210f

[271] Cf. Brynjolfsson & McAfee (2014), p. 200

[272] Cf. Bernhard, et al. (2013), p. 2934

[273] Cf. Bernhard, et al. (2013), p. 2935; Rodriguez (2012), p. 1; Yuan & Powell (2013), p. 7

In the other hand the *xMOOCs* model (content-based MOOC) refers to a more traditional learning approach. They mainly use video presentations, short quizzes and testing, often used as an extension of the pedagogical models practiced within the educational institutions.[274]

How MOOCs work by an example of edX

To gain a better understanding about how MOOCs work, the online learning destination *edX*, founded by Harvard University and MIT in 2012, is highlighted. *edX* provides more than 650 in various subjects, offered by the world's leading universities, nonprofits and institutions.[275] The courses are usually offered for free. There is also the possibility to gain a verified certificate when successful completing a course. Therefore, fees between USD 50 to USD 100 are common. Most of the courses are designed so the learner can decide his own pace. The course provider usually estimates the length of the course, as well as weekly effort. The courses combine the classical xMOOCs (content-based) and the cMOOCs (social learning environment) approach.[276]

The learning sequences are divided into video sessions, interactive learning tools and assignments or exams. Videos can be classic lectures, class discussions or tablet captures. The *edX* video player allows starting and pausing videos whenever needed. Additionally, the learner can control speed, volume, screen size and captions of the videos. The transcript is shown next to the player. By selecting a word within the transcript, the video jumps to the selected part. Additionally, videos and transcripts can be downloaded to view them later in offline mode.[277]

Videos are an essential part of MOOCs because they transfer the lessons' content to the student. As a consequence, it is always the question how to

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[274] Cf. Bernhard, et al. (2013), p. 2935; Rodriguez (2012), p. 1; Yuan & Powell (2013), p. 7

[275] E.g. MIT, Harvard University, Berkeley University of California, CALTECH, University of British Columbia, Princeton University, Georgia Tech, RWTH Aachen, TU München, ETH Zürich, etc.

[276] Cf. https://www.edx.org/ [16.02.2016]

[277] Cf. https://www.edx.org/ [16.02.2016]

maximize students learning output while keeping video production time and costs at a minimum. An important factor to engage students is to interest and motivate them. Table 7 shows the findings by Guo, Kim, & Rubin (2014), and their recommendations how to produce engaging MOOC videos.

Table 7: Summary of the main findings and recommendations in video production[278]

Finding	Recommendation
Shorter videos are much more engaging.	Invest heavily in pre-production lesson planning to segment videos into chunks shorter than 6 minutes.
Videos that intersperse an instructor's talking head with slides are more engaging than slides alone.	Invest in post-production editing to display the instructor's head at opportune times in the video.
Videos produced with a more personal feel could be more engaging than high-fidelity studio recordings.	Try filming in an informal setting; it might not be necessary to invest in big-budget studio productions.
Khan-style tablet drawing tutorials are more engaging than PowerPoint slides or code screencasts.	Introduce motion and continuous visual flow into tutorials, along with extemporaneous speaking.
Even high quality pre-recorded classroom lectures are not as engaging when chopped up for a MOOC.	If instructors insist on recording classroom lectures, they should still plan with the MOOC format in mind.
Videos where instructors speak fairly fast and with high enthusiasm are more engaging.	Coach instructors to bring out their enthusiasm and reassure that they do not need to purposely slow down.
Students engage differently with lecture and tutorial videos	For lectures, focus more on the first-watch experience; for tutorials, add support for re-watching and skimming.

To test the gained knowledge, interactive assignment tools are used. These can be part of either learning sequences or an exam. The questions can be graduated and may have due dates, depending on the individual course. The learner has to fill in the answer and check if it is right. Some assignments also include a "show answer" button. The problems covered within assignments are separated into basic problems and STEM problems. Basic problems are handled by easy tools like multiple choice (standard, checkbox

[278] Illustration based on Guo, Kim, & Rubin (2014), p. 2

or dropdown problems), fill-in-the-blank, basic numerical answer, drag and drop and pointing on picture problems. More specific STEM problems make often use of interactive learning tools such as math expression, chemical equation, circuit schematic, molecule binder, protein builder, code grader or zooming diagrams tools. Additionally, there are also open response assessments or problems that ask to write one or more paragraphs or to upload a file. In a next step, students are asked to give self and provide peer assessment.[279]

Additional course sections such as a discussion board, a course wiki as well as meet-ups, hangouts and social media, cover the cMOOCs part. These services help students to work together both online and offline. In discussion forums, students can introduce themselves and ask questions about the course material. Some courses also require weekly or daily discussions. The course wiki is an editable database of all information covered by the course. Also students can have access to edit the database. Meet-ups, hangouts and social media are great opportunities to find study buddies and increase the likelihood of successfully completing the course. Students can join the *edX* community on social media, some of the courses also offer individual social media pages.[280]

MOOCs for employee development

Related to the needs of future workforce, MOOCs combine preferable characteristics for both older and younger generations as they are discussed in chapter 2.2.5. Younger workers are familiar with digital education tools and prefer their own flexible classrooms by using online services. Older workers benefit because they have a higher need for clear instructions, quick feedback and often prefer self-paced learning, as they need more time to learn. Learners are more motivated and more effective due to the possibility of self-paced learning. Practical knowledge is transferred in a virtual way, by using interactive assignment tools.

[279] Cf. https://www.edx.org/ [16.02.2016]

[280] Cf. https://www.edx.org/ [16.02.2016]

When using MOOCs, companies have different possibilities how to organize the participation but also content of the courses. Table 8 describes characteristics to be considered when designing MOOCs for employee development.

Table 8: MOOCs Characteristics[281]

Characteristics	Model	Description
Enrollment	Mandatory	Companies order enrollment in MOOCs to actively develop the skills level of employees.
	Voluntary	Employees are allowed to participate in courses, but skills development is not necessary to fulfill the job.
Participation	Work Time	Employees are allowed to attend courses within working hours. The available amount to spend on MOOCs must be defined and monitored.
	Free Time	Employees are not allowed to attend courses within working hours. This is referred as a more common approach.
Topic	Free	Employees are allowed to choose the course topic without limitations by the company. In this case, the portfolio of the provider is the limitation.
	Limited	The providers' portfolio gets tailored to specific companies' needs. Participants can choose out of the courses available for their company, department or even individual job.
	Defined	Employees get a predefined list of courses to attend. They are not allowed to choose or change between courses.
Content	Internal content	MOOCs are designed to teach employees about the companies' product, processes or culture. The content must be provided by the company itself
	External content	Content of the courses does not refer to company specific data. MOOCs provider

281 Illustration is based on interviews with Magna Powertrain PD&T experts

		designs the courses independently.
	Mixed content	Core topics are designed to companies' content and further added by external content.
Access	Not Limited	Employees are allowed to enroll in as many courses they like
	Limited	The number of courses allowed to enroll is limited within a certain time frame.
Certificate	Not available	Learners get no certificate when finishing a course.
	Available; paid by company	Learners receive a proven certificate when successfully finishing the course. The certificate is paid by the company to support the employee.
	Available; paid by employee	Learners receive a proven certificate when successfully finishing the course. The employee has to take the costs on his own.
Target group	Blue-collar	The training aims to reach blue-collar workers. Therefore, organizational details have to be adapted such as internet connection / access, training needs, skills level of employees etc.
	White-collar	The training is designed to teach white-collar workers. Therefore, organizational details have to be adapted such as internet connection / access, training needs, skills level of employees etc.
Competence Set	Personal Effectiveness	The content focuses on the development of personal competences such as e.g. passion, self-awareness, emotional control, ethics and respect, etc.
	Technical	Course content is designed to develop capabilities related to technical disciplines. This includes e.g. innovation management, quality management or continuous improvement.

	People Leadership	Learners gain expertise about leading people which also includes topics e.g. teamwork, communications or change management.
	Business	General business related topics are transferred in this kind of courses. This includes e.g. sales, marketing, finance or entrepreneurial thinking.
Position Level	Senior and Executive Level	Course attendees are highly experienced at the topic. These courses concentrate on advanced technics and detailed topics.
	Management Level	Course attendees are already used to the basic content of the topic and thus require more detailed course content to build up expertise.
	Individual Contributor Level	The content is designed to meet the existing knowledge and skills gaps of tenderfoots. Therefore, courses are often described as introduction courses. No prior knowledge is required.
Number of employees enrolled	Number of licenses n	The company is willing to pay for n licenses within a certain timeframe.
License model	Fix	Employees with access to the online training platform are defined in advance. Only these employees are allowed to enroll in online courses.
	Rotating	A predefined number of employees are allowed to use the online platform for a certain period of time. After this period, the licenses are transferred to different employees for the next period.
	Free	All employees are allowed to use the online platform at any time. There is a specific number of licenses available for the entire organization.
Limitations of attendance	Available work time t in %	The company has to define a certain standard to which extend participation is allowed. This is important if training is mandatory or participation is allowed during regular work time.

	Costs per course	The company sets a certain limit of accessible courses due to their costs.

Summary of MOOCs in Business

MOOCs are already referred as high potential training concept in education but also employee development. They highly benefit workforce because employees can organize training as needed. MOOCs can be used to train both blue- and white-collar workers. Available topics reach from business management, sales, marketing, etc. also to manufacturing specific topics like supply chain management, operations management, programing or other related STEM fields.

As discussed in prior chapters, their highest benefits for organizations are seen in:

1. **High availability**
   Employees can enroll wherever and whenever wanted. Most MOOCs also allow download of material, which allows also offline learning.
2. **Self-organization**
   Employees can decide on their own which courses to attend and steer their learning progress individually. This avoids conflicts with working time and enables the attendee due to his individual learning pace.
3. **Direct application**
   MOOCs can be started easily per mouse-click and thus learning immediately starts. It is not necessary to organize training sessions (trainer, location, minimum number of attendees, etc.) or wait several weeks till training starts. MOOCs user can directly jump into the lessons and thus instantly apply their gained knowledge.

Using the prior evaluated characteristics of MOOCs, organizations can develop their own concepts of using MOOCs. Table 9 shows all defined characteristics summarized in a morphological box, allowing the training provider to have a generic overview of his options.

Table 9: Morphological Box MOOCs[282]

<table>
<tr><th>Characteristics</th><th colspan="12">Features</th></tr>
<tr><td>Enrollment</td><td colspan="6">Mandatory</td><td colspan="6">Voluntary</td></tr>
<tr><td>Participation</td><td colspan="6">Work Time</td><td colspan="6">Free Time</td></tr>
<tr><td>Topic</td><td colspan="4">Free</td><td colspan="4">Limited</td><td colspan="4">Defined</td></tr>
<tr><td>Content</td><td colspan="4">Internal</td><td colspan="4">External</td><td colspan="4">Mixed</td></tr>
<tr><td>Access</td><td colspan="6">Not Limited</td><td colspan="6">Limited</td></tr>
<tr><td>Certificate</td><td colspan="4">No</td><td colspan="4">Yes – company</td><td colspan="4">Yes – private</td></tr>
<tr><td>Target Group</td><td colspan="6">Blue-collar</td><td colspan="6">White-collar</td></tr>
<tr><td>Competence Set</td><td colspan="3">Personal Effectiveness</td><td colspan="3">Technical</td><td colspan="3">People Leadership</td><td colspan="3">Business</td></tr>
<tr><td>Position Level</td><td colspan="4">Senior and Executive</td><td colspan="4">Management</td><td colspan="4">Individual Contributor</td></tr>
<tr><td># of employees</td><td colspan="4"><50</td><td colspan="4">50 – 250</td><td colspan="4">>250</td></tr>
<tr><td>License model</td><td colspan="4">Fix</td><td colspan="4">Rotating</td><td colspan="4">Free</td></tr>
<tr><td>Limitation</td><td colspan="6">Costs</td><td colspan="6">Time</td></tr>
</table>

Companies already use MOOCs in employment development. Therefore, also MOOCs providers have identified the potential to cooperate with companies and therefore installed corporate programs such as e.g. *Udemy for Business*.[283]

Nevertheless experts are skeptical about the implementation of MOOCs in business. If attendance is mandatory, both motivation to join after work and open timeslots to join during work time is less likely expected. Against that, voluntary participation rises fear attendance is getting unspoken mandatory und thus causes pressure on the learner and lowers the learning success. A common problem in PD&T is that employees motivated and highly willing to

[282] Illustration based on literature research and expert discussions.

[283] Cf. https://business.udemy.com/ [17.02.2016]

participate voluntary training usually have less urgent training needs than those who resist against further training.

Learning factory

Learning factories follow the philosophy of hands-on experience combined with minimal theoretical content, focusing on manufacturing processes and principles.[284]

They usually focus on Lean Manufacturing and energy efficiency optimization. Therefore it is important these factories comprise real production processes by physical means (machining, assembly, logistics, etc.) but also digital environment (planning, modeling, simulation, visualization tools, etc.).[285] Thus, the learning factory approach can be used to handle mechatronics and ICT topics related to the fourth industrial revolution. [286]

Types of learning factories

Learning factories can be divided into six different types. They mainly differ in terms of applicants (academia or industry), communication channel (explained in example three), and content.[287]

1. The **industrial application scenario** is used as a training method for developing employees of all hierarchical levels. The participants get the chance to discover Lean principles and methods and apply them directly in real life scenarios. Thus, there is no cost pressure or risk of failure within the training environment. These sessions usually include multi-day workshops, attended by approximately 10-15 participants. There are usually three different phases: Lean Understanding, Lean Core Elements and Lean Culture.

[284] Cf. Eberhard, et al. (2015), p. 3

[285] Cf. Rentzos, Mavrikios, & Chryssolouris (2015), p. 31 ; Wagner, et al. (2012), p. 110

[286] Cf. Faller & Feldmüller (2015), p. 88

[287] Cf. Abele, et al. (2015), pp. 4

2. The learning factory is also used within academia, referred as **academic application scenario**. It represents a physical education platform and includes an educational platform for an activity-based course. There are different didactical methods used like e.g. blended learning, combination of online self-learning, frontal teaching and hands-on training in the learning team. As the classic manufacturing job profile moves increasingly into the direction of ICT, students also have to learn about these tools and processes.
3. The **remote learning scenario** or **teaching factory concept** is a promising paradigm for integrating factory environments with classrooms. Their aim is to establish a two-way knowledge exchange between industry and academia. The participants are remotely located teams of engineers and students/researchers. Thus, this type of learning factory aims to establish a two-way knowledge exchange between industry and academia. On the one hand side, real manufacturing environment is transferred into the classroom, referred as “factory-to-classroom” knowledge communication channel. The “lab-to-factory” knowledge communication channel works in the opposite direction. In this scenario, engineers are seen as knowledge receivers. Didactic equipment, which is installed at the academic facilities, can be used to demonstrate research results of students and researchers. The new generated technological concepts can then be transferred back to industry.
4. A learning factory focusing on systems learning is called **changeability research scenario**. These types often use transformable production platforms and modules, to easily reconfigure systems layout and functionality.
5. Very similar to the industrial application scenarios, the **consultancy application scenario** evolved. This type refers to the learning factories established by the global consulting company McKinsey for experiential learning for capabilities in various fields of application and industry branches.
6. Learning factories can be also used as **demonstration scenarios**. In this case, future production concepts and technologies can be demonstrated within one-day workshops. Specifically, it was designed to give SME and non-industrial stakeholders a basic understanding of the interaction between human workers automation technologies and

ICT. Usually, the night before the participants order a customized part, which will be produced over night, waiting for them at the next day to be assembled by the participants themselves. Thus, the participants gain insights about data consistency from design to assembly, the potential of ICT, the decentralized production and logistics and the heightened flexibility in the state-of-the-art production.

Examples of learning factories

Based on a study conducted within the European Initiative on Learning Factories, a typology of learning factories was created. This typology includes a variety of features that characterise learning factories. It includes different target groups, selected industries but also various didactical concepts beeing applied. Figure 18 shows this typology in detail and addtionally highlightens features common used.[288]

[288] Cf. Tisch, et al. (2013), p. 581

characteristic	features					
operating organization	industry	consulting	**university**	technical college	professional school	
type of use	**education / training**	research	further industrial use			
industrial target groups	operational staff	**engineer**	manager			
academic target groups	students	research staff / post graduated				
other target groups	lean experts / lean specialist	other consultants				
selected industries	**mechanical and plant industry**	**automotive industry**	chemical industry	electrical industry	insurance, banks, etc.	
product	real product	arteficial (didactic) product				
production process	machining	assembly	logistics	IT	indirect	productio n
module content	**process impr.**	diagnosis	system design	quality control		
	quality	material flow	techn. opt.	lean transfer		
integrated departments	**production**	distribu-tion	pur-chasing	ideas mgmt.	design / develop-ment	prod. planning / control
integrated teaching methods	**presentation**	**demon-stration**	tutorial	web-based training	simulation game	
	discussion	case study	role play	experimen-tal game	learning cells	

Figure 18: Learning factory typology[289]

For large and small-and-medium-sized enterprises (SME), the University of Split developed the Lean and Green concept for manufacturing industry, services, banks, etc. A team existing of employees from all departments and hierarchy levels and external experts from University gets defined to implement the concept within an organization. This process usually takes about six months and includes theoretical, practical and didactic games and pilot application on shop floor level. The training program is divided into three major steps, starting with the basic philosophy of Lean, the tools and methods of Lean and to acquire Lean Thinking. Table 10 gives detailed overview of the included Lean Principles.[290]

[289] Tisch, et al. (2013), p. 581

[290] Cf. Veza, Gjeldum, & Mladineo (2015), p. 136

Table 10: The three steps of the Lean and Green training concept[291]

Step 1: Basics of Lean	Step 2: Elements of Lean	Step 3: Lean Thinking
Toyota Production System	Just-In-Time	Leadership for Lean
Lean principles	Heijunka (line balancing)	Lean in other areas (e.g. administration, education, etc.)
Standardization of work	Push-Pull production	Kata for Improvement
7+1 types of waste	One piece flow	Visual management (Obeya)
Quality techniques	Quick change-over (SMED)	
Didactic games	Tact time	
	Supermarket	
	Kanban	
	Kaizen	
	Value Stream Mapping	

As an example, Graz University of Technology installed a learning factory for research, education and corporate employee trainings. The learners generate knowledge by assembling a scooter consists of about 60 components, starting with a non-optimized process and further step-by-step improving the process by using the techniques they have learned within upfront theory sessions. The content of these training sessions focuses mainly on methods and principles of Lean Management, process observation, factory design, value stream analysis, etc., depending on the specific participators needs. Additionally, research projects within the learning factory concentrate on Industry 4.0 related technologies e.g. RFID for process optimization, Big Data Analysis or modern wearables.[292]

[291] Illustration based on Veza, Gjeldum, & Mladineo (2015), p. 136

[292] Cf. http://industrie40.tugraz.at/ [22.02.2016]

How to apply the learning factory concept in industry

Following the *industrial application scenario*, learning factories can be used to develop Lean Management skills. This type is applicable to employees of all hierarchical levels and can be used as basic Lean Manufacturing training. Usually about 10-15 participants attend these kind of multiday workshops.

The training methods can be approached for new employees but also experienced workers. Teaching employees the philosophy and tools needed to survive in a Lean environment initially can make their jobs easier from day one. Also experienced operations management trainings can be applied to build their awareness about Lean Manufacturing and the workforce within shop floor.

Within this teaching method, employees should get a basic understanding about Lean Management and the related processes. They get skills for decision making and problem solving, as well as teamwork and standardized work. Thus, this method focuses mainly of the development of soft skills. Table 11 gives a brief overview how learning factory concepts can be distinguished.

Table 11: Learning factory characteristics[293]

Characteristics	Model	Description
Enrollment	Mandatory	Companies order enrollment in Learning Factory courses to actively develop their employee's Lean skills.
	Voluntary	Employees are allowed to participate in courses, but skills development is not necessary to fulfill the job.
Participation	Work Time	The courses are executed within normal working time.
	Free Time	The courses are organized during workers' free time.
Content	Standard	The Learning factory applies a standard program without consideration of individual needs of their customers.
	Individual	An individual training model gets designed by adapting the standard content to the company specific needs.
Competence Set	Personal Effectiveness	The content focuses on the development of personal competences such as e.g. passion, self-awareness, emotional control, ethics and respect, etc.
	Technical	Course content is designed to develop capabilities related to technical disciplines. This includes e.g. innovation management, quality management or continuous improvement.
	People Leadership	Learners gain expertise about leading people which also includes topics e.g. teamwork, communications or change management.
	Business	General business related topics are transferred in this kind of courses. This includes e.g. sales, marketing, finance or entrepreneurial thinking.
Position Level	Senior and Executive Level	Course attendees are highly experienced at the topic. These courses concentrate on

[293] Illustration is based on interviews with Magna Powertrain PD&T experts

		advanced technics and detailed topics.
	Management Level	Course attendees are already used to the basic content of the topic and thus require more detailed course content to build up expertise.
	Individual Contributor Level	The content is designed to meet the existing knowledge and skills gaps of tenderfoots. Therefore, courses are often described as introduction courses. The courses transfers basic knowledge, previous knowledge is not required.
Target group	Blue-collar	The training aims to reach blue-collar workers. Therefore, organizational details and content have to be adapted due to their work time model (e.g. shift) and field of expertise.
	White-collar	The training is designed to teach white-collar workers. Therefore, organizational details and content have to be adapted due to their work time model (e.g. all-in contract) and field of expertise.
Installation	Internal	The learning factory is installed at the company and thus is accessible for employees whenever needed. It implies capital expenditure for equipment and responsibility to maintain the installations and courses.
	External	Companies use training installations of external providers. This implies restricted access but also minimal costs for equipment and maintenance.
Execution	Initial	The learning factory is used to give introductory courses to new employees. This is already a common method to teach new employees how to handle the installed equipment and understand the values and processes of the company.

	Regular	Courses are designed on a regular basis that requires the employee to get in contact with the installed technologies in a certain cycle.
	Irregular	Training sessions within the learning factory are conducted on demand.
Number of employees enrolled	Number of licenses n	The company is willing to pay for n licenses within a certain timeframe.
Limitations of attendance	Available work time t in %	The company has to define a certain standard to which extend participation is allowed. This is important if the training is mandatory or participation is allowed during regular work time.
	Costs per course	The company sets a certain limit of accessible courses due to their costs.

Summary of learning factories in business

Learning factories combine minimal theory with a high amount of practical experience and thus are already used to train manufacturing specific knowledge e.g. of Lean Manufacturing and increasingly Industry 4.0. Analyzing literature and interviewing experts shows three major benefits of learning factories:

1. **Hands-on experience**
   Experts refer hands-on experience as most important to understand the challenges in manufacturing and how to deal with it. In learning factories, attendees directly apply gained knowledge by using real equipment.
2. **Making failures is allowed**
   Learning factories are places to try out what is learned in theory. If context is not fully understood, or real life situations slightly differ from theory, this results in making failures. On-the-job failures can often harm companies dramatically and therefore should be prevented as possible. In learning factories, attendees can make failures without harming the company, and directly know how to deal with similar challenges in real life.

3. **Universal application**
   Learning factories can be designed to train diverse participants. For example, they can be applied to give engineers an understanding of real life applications but also to expand operators' knowledge about manufacturing principles and methods that they can use in daily business. Therefore, a wide range of employees can be trained according to specific needs of an organization.

Due to the high number of different learning factory concepts and it's implied characteristics, companies have to decide very carefully about which fit into their training needs and strategy. As an example, companies need to decide between installing their own learning factory and collaborating with external providers. Both solutions highly differ in terms of e.g. infrastructure needed, capital requirements of equipment, administrative work, maintenance of installed equipment, supervision of the courses and continuous adaption of training content. Additionally, the access to the learning environment plays an important role in terms of flexibility and short-handed changes.

When analyzing the input of experts and literature, many characteristics of learning factories implementation concepts can be identified. Therefore, a framework has been established to show particular points to be considered when designing learning factory training (See Table 12).

Table 12: Morphological Box learning factory[294]

<table>
<tr><th>Characteristics</th><th colspan="12">Features</th></tr>
<tr><td>Enrollment</td><td colspan="6">Mandatory</td><td colspan="6">Voluntary</td></tr>
<tr><td>Participation</td><td colspan="6">Work Time</td><td colspan="6">Free Time</td></tr>
<tr><td>Content</td><td colspan="6">Standard</td><td colspan="6">Individual</td></tr>
<tr><td>Target Group</td><td colspan="6">Blue-collar</td><td colspan="6">White-collar</td></tr>
<tr><td>Competence Set</td><td colspan="3">Personal Effectiveness</td><td colspan="3">Technical</td><td colspan="3">People Leadership</td><td colspan="3">Business</td></tr>
<tr><td>Position Level</td><td colspan="4">Senior and Executive</td><td colspan="4">Management</td><td colspan="4">Individual Contributor</td></tr>
<tr><td>Installation</td><td colspan="6">Internal</td><td colspan="6">External</td></tr>
<tr><td>Execution</td><td colspan="4">Initial</td><td colspan="4">Regular</td><td colspan="4">Irregular</td></tr>
<tr><td># of employees</td><td colspan="4"><50</td><td colspan="4">50 – 250</td><td colspan="4">>250</td></tr>
<tr><td>Limitation</td><td colspan="6">Costs</td><td colspan="6">Time</td></tr>
</table>

Experts refer the learning factory as highly beneficial concept to develop practical knowledge, but also to understand the practical realization of theoretical content. The most critical point in designing a learning factory employee development program relies on the question if using an existing learning factory by an external provider or building an individual. Beside the prior discussed cost factor, also strategic factors must be considered e.g. execution strategy, number of employees and number of training sessions planned, participation time, customization of the learning factory (machines, processes, products produced, etc.) to company needs. Therefore, it is important to consider the prior discussed dimensions and extend them if it is required by the individual situation.

[294] Illustration based on literature research and expert discussions.

Fab Lab

In recent years the trend of personal fabrication revolutionizes manufacturing in terms of design, production and distribution of goods.[295] It is often referred as Makers Movement, the trend to a new era of inventing products and do-it-yourself production.[296]

Out of the MIT's Center for Bits and Atoms lecture *"How To Make (almost) Anything"* by Neil Gershenfeld, the Fab Labs have emerged. Originally designed for ten students, about a hundred showed up to learn and work with digital fabrication and computation tools, producing the products they ever dreamed of. Surprisingly, students had relatively little technical experience e.g. artists and architects joined the class. Their aim was not to publish a paper, a file or a patent. Their motivation was to develop a product they always wanted to have but didn't exist. Most students started with skills in arts and crafts rather than advanced engineering and managed to design and create complete applicable systems.[297]

Within Fab Labs (which is an abbreviation for "fabrication laboratories" of "fabulous laboratories")[298] students start learning by making and creating. Thus, it improves students' creativity, design and entrepreneurial thinking skills. Additionally, students are able to work with up-to-date equipment and this gain deep knowledge about the machines. They also learn about the materials, about design processes and the engineering of inventions and innovations.[299]

Therefore, makerspaces and Fab Labs are promoted to have high potential addressing future industry needs by various institutions (e.g. the Innovative Pedagogy Report 2013 and the NMC Report 2014, 2015). It is the combination of action-oriented learning, combined with project-based

[295] Cf. Mota (2011), p. 279

[296] Cf. Hagel, Brown, & Kulasooriya (2013), p. 2

[297] Cf. Gershenfeld (2005), pp. 5

[298] Cf. Gershenfeld (2012), p. 47

[299] Cf. http://www.fabfoundation.org/ [02.03.2016]; Johnson, et al. (2014), pp.14; Johnson, et al. (2015), pp. 40

classes, which makes fab labs an innovative teaching method. [300] A study of Forest, et al. (2014) reported that 90% of the students reported significant impact on their design skills, and 80% confirmed positive impact on their manufacturing skills after attending the Georgia Institute of Technology makerspace.[301]

To become part of the Fab Foundation, a Lab must fulfill 4 criteria:[302]

1. A Fab Lab must be open to the public at least part of the time each week. The machines must be available for free or in-kind service/barter for material used.
2. Fab Labs and their founding individuals must support and subscribe to the Fab Lab charter.
3. Fab Labs have to share a basic set of tools and processes.
4. Fab Labs must participate in the global Fab Lab network, being part of a global, knowledge-sharing community.

It is important every Fab Lab contains a common set of tools that includes:[303]

1. Laser cutter for making 3D structures from 2D designs
2. Large CNC mill for making furniture and housing
3. NC knife and smaller mini-mill for making circuits and molds for casting
4. 3D printers
5. Electronics workbench and a suite of tooling and material.

First universities already installed Fab Labs or makerspaces and developed adequate courses. If we have a look at the actual Top 5 Universities according to the Times Higher Education Ranking in engineering and technology, all of them have already implemented makerspaces, which are open for students and actively used in education. These courses usually use

[300] Cf. Johnson, et al. (2014), pp.14; Johnson, et al. (2015), pp. 40; Sharples, et al. (2013), p. 33

[301] Cf. Forest, et al. (2014), p. 21

[302] Cf. http://www.fabfoundation.org/ [02.03.2016]

[303] Cf. http://www.fabfoundation.org/ [02.03.2016]

a combination of theoretical input and practical sessions. They last between weeks and several months or semesters, including several sessions per week. The courses are often handled as group projects whereas long-term courses e.g. at MIT or Stanford favor individual work.[304]

Based on MIT's course *"How to make (almost) Anything"*, the international Fab Academy got established as a complementary to the available courses within higher education. It is referred as distributed educational system, specialized to teach students hands-on experience with digital fabrication tools and how to envision, prototype and document their ideas. The program requires of 5 months students part-time participation. The Fab Academy Diploma is acquired as a result of several Fab Academy Certificates, which are evaluated by students' acquired skills rather than time or credits. At the international Fab Academy, students have to plan and execute a new project each week. Within several sessions they turn their ideas into bits and further into atoms resulting in physical objects.[305]

Students gain theoretical knowledge via viewing and participating in global webcasts, broadcasted weekly, lasting for three hours. These sessions contain necessary input about the tools and machines, design and production processes, Information and Communication Technologies (ICT) and materials. Additionally, they provide insights in project management and legal questions, such as invention, intellectual property, and income related topics. These video lectures are provided by the Fab Academy faculty and its' global leading experts. The Fab Academy faculty also supervises the academic content and guides research.[306]

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[304] Cf. https://www.timeshighereducation.com/world-university-rankings/2016/engineering-technology#!/page/0/length/25 [11.02.2016];
https://productrealization.stanford.edu/ [09.03.2016];
http://www.mce.caltech.edu/research/lab [09.03.2016];
http://fab.cba.mit.edu/about/faq/ [09.03.2016]
http://www.eng.cam.ac.uk/news/3d-printing-laboratory-students [03.09.2016]
http://invent.citris-uc.org/ [09.03.2016]

[305] Cf. http://fabacademy.org [09.03.2016]

[306] Cf. http://fabacademy.org [09.03.2016]

Practical knowledge is provided by 2/3 days per week actively working with the digital fabrication tools at the local Fab Labs. Lab instructors are aboard to provide personal help to the students. These instructors also supervise and evaluate Certificates, develop and disseminate instructional material, and assist with projects.[307]

To attend the course, a minimum knowledge about digital fabrication tools and processes (2D and 3D modeling, digital fabrication, electronics programming, web design and development) is required. If proficiency in these disciplines is rated Low or Medium, the program should be considered as a full-time program. Anyone can apply to attend the Fab Academy Diploma program. Depending on the individual Fab Labs, also partial and full scholarships are available to cover the tuition fees for students in economic difficulties.[308]

Fab Labs can be used by various parties e.g. universities and schools, but also companies, agencies, small-and-medium sized enterprises (SME) and start-ups according to the experts. In this connection, employees get the possibility to develop and fabricate their own ideas and products and get valuable insights into digital fabrication. The Fab Lab staff is responsible to assist the users with support and solutions along the product design process from idea generation to market launch.

Within employee development programs, it can be used to train the contact with digital production equipment via hands-on experience. This includes the at least basic hardware for Fab Labs such as 3D printers, laser cutters, CNC milling machines and electronic tools. Thus, skills in Mechanics, Electronics and Software are developed as well as advanced manufacturing technologies get explored. Theoretical content usually includes basics of rapid prototyping, business and product development skills. This includes the product itself but also business models and product developments methods like TRIZ, design thinking, value engineering, prototype to product, target costing, best of benchmarking, SWOT, project management and so forth. Learners get used to entrepreneurial thinking, creativity techniques and

[307] Cf. http://fabacademy.org [09.03.2016]

[308] Cf. http://fabacademy.org [09.03.2016]

design thinking. The learners are often required not just to develop a new product, but also finding economic applications for their product and developing business plans.

The didactical background refers to action-oriented education and project-based learning. The concept can include characteristics of self-organized learning, collaborative learning and problem-oriented learning depending on the course set-up.

Table 13 gives an overview of possible course characteristics to set up adequate training sessions.

Table 13: Fab Lab characteristics[309]

Characteristics	Model	Description
Enrollment	Mandatory	Company orders use of Fab Labs to actively develop the skills level of employees.
	Voluntary	Employees are allowed to participate in courses and use the Fab Lab on a voluntary base.
Participation	Work Time	The Fab Lab can be used within normal working hours.
	Free Time	Employees get access only within private time. Working hours are not used to cover it as an employee training.
Topic	Free	Fab Lab users are allowed to work on their own products.
	Defined	The company predefines the projects and products to work on.
Theory sessions	Initial	Theoretical knowledge is provided within an initial training session. This training session can last from hours to days, depending on the used equipment.
	Regular	Regular theory sessions are used to teach the theoretical content. The time periods can last from weekly to monthly sessions, depending on the project plan. If employees

[309] Illustration is based on interviews with Magna Powertrain PD&T experts

		are allowed to use the lab whenever wanted, an initial training session is needed.
Target group	Blue-collar	The training aims to reach blue-collar workers. Therefore, organizational details and content have to be adapted due to their work time model (e.g. shift) and field of expertise.
	White-collar	The training is designed to teach white-collar workers. Therefore, organizational details and content have to be adapted due to their work time model (e.g. all-in contract) and field of expertise.
Competence Set	Personal Effectiveness	The content focuses on the development of personal competences such as e.g. passion, self-awareness, emotional control, ethics and respect, etc.
	Technical	Course content is designed to develop capabilities related to technical disciplines. This includes e.g. innovation management, quality management or continuous improvement.
	People Leadership	Learners gain expertise about leading people which also includes topics e.g. teamwork, communications or change management.
	Business	General business related topics are transferred in this kind of courses. This includes e.g. sales, marketing, finance or entrepreneurial thinking.
Position Level	Senior and Executive Level	Attendees are highly experienced at their focus area. The Fab Lab is used to increase their specific skills or contribute them by generating other knowledge e.g. entrepreneurial skills or product development and production skills.
	Management Level	Attendees have intermediate practical experience. The Fab Lab is needed to increase their specific skills or contribute them by generating other knowledge e.g. entrepreneurial skills or product development and production skills.

	Individual Contributor Level	The content or participation is designed that no prior knowledge is needed. This may imply initial theory sessions are needed.
Number of employees enrolled	Number of licenses n	The company is willing to pay for n licenses within a certain timeframe.
License model	Fix	Employees with access to laboratories are defined in advance.
	Rotating	A predefined number of employees are allowed to use the laboratories for a certain period of time. After this period, the licenses are transferred to different employees for the next period.
	Free	All employees are allowed to use the online platform at any time.
Limitations of attendance	Available work time t in %	The company has to define a certain standard to which extend participation is allowed. This is important if the training is mandatory or participation is allowed during regular work time.
	Costs per course	The company sets a certain limit of access due to the occurring costs.

To prepare the participants how to use the equipment and give them the basic theoretical background of business plans, rapid prototyping, etc., classic lectures must be conducted. Depending on the participation time model the content can be transferred by weekly theory sessions. Therefore, classical class sessions or digital sessions via webcasts or recorded videos can be used. An introduction course is needed to make sure learners are able to immediately handle the equipment.

First companies report beneficial impact on innovation process and culture due to the free use of Fab Labs for their employees. As an example, Airbus opened the ProtoSpace and refers reduced product development times, higher agility and improved quality as key outcome.[310] For this reason also the BMW Group has signed cooperation with UnternehmerTUM, run by the

[310] Cf. http://www.airbusgroup.com/int/en/story-overview/Shooting-for-the-moon.html [18.02.2016]

Technische Universität München. It aims to accompany and support start-ups and established companies from idea to successful business. BMW currently holds about 400 memberships.[311]

Summary of Fab Labs in employee development

Resulting from the Makers Movement trend, Fab Labs have established all over the world as institutions for teaching and innovation. It combines hands-on experience with self-paced learning and using emerging technologies. In employee development, it can be used to train more than using digitized production equipment. Reviewing literature, expert interviews and best practice examples, following benefits must be highlighted:

1. **Product Development and Entrepreneurial Thinking**
   In Fab Labs, users build a product from the very first till the very last step, including all iterations. They learn methods of product and business development and often find economic applications for their product. For companies, there is high potential to accelerate innovation process and improve quality of actual products.
2. **Production technologies**
   During product development process, learners get in touch with many production technologies to fabricate functional prototypes. Depending on the product, they develop skills in various fields e.g. mechanics, electronics or software by research and trial. Thus, employees gain interdisciplinary insights in production technologies and processes.
3. **Innovation network**
   Fab Labs are institutions that can be used by all kind of people for free or a certain fee. Users may be students, start-ups, employees of SMEs and large corporates but also people that are interested to create, even if not a student or employed. Thus, Fab Labs bring together a high number of individuals with special interests and fields of expertise. A network of highly motivated thinkers and makers evolves, encouraging idea exchange and going new business paths (e.g. in new industries or new applications)

[311] Cf. http://www.unternehmertum.de/index.html [18.02.2016]

Creating prototypes in Fab Labs is no typical employee development method. There are less organizational boundaries, less input of trainers, mentors and coaches and also not necessarily a training plan, creating a not transparent and not traceable learning processes. It combines self-paced learning with hands-on experience, added by a highly motivated network of inventors and innovators. It is important to understand that learners get more than skills in using digitized production equipment. They gain highly interdisciplinary knowledge in product and business development and additionally create innovative products. To create a Fab Lab training suitable for the individual needs of a company, a framework has been developed based on literature and expert interviews. (see Table 14)

Table 14: Morphological Box Fab Lab[312]

<table>
<tr><th>Characteristics</th><th colspan="12">Features</th></tr>
<tr><td>Enrollment</td><td colspan="6">Mandatory</td><td colspan="6">Voluntary</td></tr>
<tr><td>Participation</td><td colspan="6">Work Time</td><td colspan="6">Free Time</td></tr>
<tr><td>Topic</td><td colspan="6">Free</td><td colspan="6">Defined</td></tr>
<tr><td>Theory sessions</td><td colspan="6">Initial</td><td colspan="6">Regular</td></tr>
<tr><td>Target Group</td><td colspan="6">Blue-collar</td><td colspan="6">White-collar</td></tr>
<tr><td>Competence Set</td><td colspan="3">Personal Effectiveness</td><td colspan="3">Technical</td><td colspan="3">People Leadership</td><td colspan="3">Business</td></tr>
<tr><td>Position Level</td><td colspan="4">Senior and Executive</td><td colspan="4">Management</td><td colspan="4">Individual Contributor</td></tr>
<tr><td># of employees</td><td colspan="4"><50</td><td colspan="4">50 – 250</td><td colspan="4">>250</td></tr>
<tr><td>License model</td><td colspan="4">Fix</td><td colspan="4">Rotating</td><td colspan="4">Free</td></tr>
<tr><td>Limitation</td><td colspan="6">Costs</td><td colspan="6">Time</td></tr>
</table>

According to the interviewed experts, the highest potential of Fab Labs is shown in the innovation potential. Due to the public environment of Fab Labs other companies, entrepreneurs or just students share the space where innovation happens and thus legal questions must be considered. As an

[312] Illustration based on literature research and expert discussions.

example, property rights for products developed by employees, but machinery and infrastructure access financed by the employer and provided by a third party must be clearly defined. Travelling issues between work, home base and the Fab Lab must also be considered in terms of casualties but also official driven distances. E.g. in Austria, there are grey zones within law that define places of employment and the distances between them. It is expected by the experts that such regulations can demotivate employees to use a facility like the Fab Lab if conditions are not beneficial to them, but also cause problems if legal questions are not managed properly. In general, Fab Labs are more perceived as an institution for creating innovative products than to develop specific skills of employees.

4.3.3 Summary training methods for future industrial workforce

To develop in future suggested skills, many didactical concepts referring to hands-on experience, project-oriented learning, self-paced-learning, etc. can be identified. Literature and experts suggest different approaches to develop the right skills with respect to digitized manufacturing and the demographic change.

To the interviewed experts, it was difficult to suggest or develop new employee development methods and thus they suggested noticeable and favorable actual training methods with respect to future requirements. As a result, three training methods aiming to develop specific skills for future industrial workforce are identified. As discussed in prior chapters, these methods are MOOCs, Learning Factories and Fab Labs. A single solution to develop the entirely needed skills set was not identified.

5 Conclusion and Outlook

Digitization often creates the impression that human labor is being completely replaced by machines and thus generates fear and creates resistance against new technologies. Repetitive routine tasks in manufacturing have been identified at high risk of being substituted by machines. Human labor will be center of tasks appropriate to specific human capabilities. The majority of tasks will require interdisciplinary experts, performing abstract and creative tasks with the responsibility to keep production lines running, intervening when necessary. The general picture of manufacturing workforce will necessarily change, as they will become highly skilled managers of complex manufacturing equipment. Technologies are expected to complement human tasks and additionally create new jobs in other related disciplines e.g. IT or data science.

Interdisciplinary competence will be essential to handle complex manufacturing equipment. A solid foundation in Science, Technology, Engineering and Mathematic (STEM) skills can be seen as the basement for a successful manufacturing career. Mechatronics will still play an important role to handle and maintain mechanical and electrical components within machines. Additionally, basic knowledge in algorithms and coding will be necessary to collaborate with digital equipment. The biggest differences between human labor and machines are presented by creative and social capabilities, enabling humans to solve novel problems and making critical decisions based on insufficient and new information. Creativity and entrepreneurial thinking will foster fast innovation, increasingly important to implement the next big leap one step faster than competition.

Education has to be adapted to meet the needs of industry. The right amount of education for apprentices, technicians and academia has to be created in order to balance the skills level of manufacturing workforce. Industry needs to play an active role, supporting theoretical input from education systems by the expertise of experienced workers (e.g. internships or guest lectures) and hands-on training.

To ensure employees are developing required skills, abilities and knowledge, companies need to create training programs based on individual job needs, as well as further education for aging employees. Initial training programs are common methods making sure employees are capable to fulfill their specific job duties. Regular and non-regular conducted training further develops the employees' technical skills and knowledge. Therefore, MOOCs, learning factories and Fab Labs have been identified as favorable methods to develop skills needed in digitized manufacturing environment. A framework has been created to adapt the identified training methods to the individual companies' needs. Therefore, manufacturing companies are recommended to:

1. Identify their specific future challenges according to internal and external factors (e.g. industry sector, market segment, business strategy, etc.) and specific impact of the fourth industrial revolution and the demographic change.
2. Prepare a clear strategy to meet these challenges. All factors directly and indirectly influencing workforce (e.g. production processes, technologies, etc.) must be considered.
3. Finally, individual workforce requirements can be defined and training models can be derived from the existing framework with respect to regional training regulations.

From an automotive industry supplier point of view, it is highly recommended to immediately start with these steps as to the increasingly turbulent environment. The fourth industrial revolution and the demographic change are already affecting the automotive industry in terms of volatile markets, changing customer needs and increasing competition. Thus, OEMs and suppliers are recommended to continuously implement innovative technologies, manufacturing processes and employee development into existing business processes to finally become an agile manufacturing company.

Additionally, employees must understand the fast changing environment and thus need to be open for change and adapt quickly. High affection to manufacturing, stubborn willingness to learn and basic technical knowledge will enable them to persist the future challenges. Industry is opposed in learning how to *"race with the machines"* rather than against them.[313]

[313] Cf. Brynjolfsson & McAfee (2014), pp. 187; Ford (2015), p. 122

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List of Abbreviations

24/7	24 Hours a Day, 7 Days a Week
2D	Two dimensional
3D	Three dimensional
AI	Artificial Intelligence
AP	Asia and Pacific Region
App/Apps	Application(s)
AWD	All-Wheel-Drive
BMW (AG)	Bayerische Motoren Werke (Aktiengesellschaft)
BMWi	Bundesministerium für Wirtschaft und Energie
CALTECH	California Institute of Technology
CEO	Chief Executive Officer
Cf.	*Latin: conferre* (English read “compare”)
CNC	Computer Numerical Controlled
CPS	Cyber-Physical System(s)
CPU	Central Processing Unit
CRELL	Center for Research on Education and Lifelong Learning
DOT	Dictionary of Occupational Titles
e.g.	*Latin: exemplia gratia* (English read *“for example”*)
ERP	Enterprise Resource Planning
et al.	*Latin: et alibi* (English read *“and others”*)
EU	European Union
EUR	Euro
GDP	Gross Domestic Product
HBS	Harvard Business School
HR	Human Resources
HRC	Human robot collaboration
i.e.	*Latin: id est* (English read “that is”)
IBM	International Business Machines Corporation
ICT	Information and Communication Technologies
IoT	Internet of Things
IT	Information Technologies
LLL	Lifelong learning
MBA	Masters of Business Administration
MES	Mechanics, Electronics and Software

MIT	Massachusetts Institute of Technology
MOOCs	Massive Open Online Courses
O*NET	Occupational Information Network
O*NET SOC	O*NET spectrum of occupations
OEM	Original Equipment Manufacturer
p.a.	Per annum
PC	Personal Computer
PD&T	People Development and Training
RNI	Rate of Natural Increase
SME	Small and medium sized enterprise(s)
STEM	Science, Technology, Engineering and Mathematics
SWOT	Strength, Weakness, Opportunities, Threads
TRIZ	*Russian: teoriya resheniya izobretatelskikh zadach*, (English read "theory of the resolution of invention-related tasks")
U.S.	United States
USD	United States Dollar
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-everything

Appendix

Appendix 1: Questionnaire interview future expectations

The interview consists of 13 semi-structured questions pertaining to three different topics. Interviews take approximately 45-60 minutes to conduct.

General Information

General information obtained from every interviewee, i.e. name, company name, field of expertise, size of the company. This will assist in evaluating and comparing all interview responses. Please fill in your personal information on the following form:

Name:			
Company Name:			
HQ Location:			
Established in:			
Company size:	Small and micro	Medium	Large
Field of expertise:			
Industry sector:			
Operating region:	National (local)	International (global)	
Confidential agreement:	Completely anonymous	Allow company name	Allow company and interviewees name

Technology Trends

In this first section, driving emerging technology trends identified and analyzed. It is important to be aware of future concepts and identify how they affect the future industrial workforce.

Question 1:
The fourth industrial revolution has many names. Paradigms like the German Industry 4.0 or the U.S. Industrial Internet of Things, including technologies like e.g. Cyber-Physical Systems, Advanced Robotics or Big Data Analytics aim to describe this evolution. How would you rate the importance of the fourth industrial revolution and its' implied concepts and what is the reason for your decision?

☐ Future language of production ☐ Just Hype

Please explain your decision:

Question 2:
The fourth industrial revolution is based on a high number of emerging technologies. Please pick three of the following technologies as to their relevance for the success of future manufacturing companies and estimate their feasibility in years. What is the reason for your choice?

Technology	Relevance	Feasibility	Reason
3D Printing (Also called additive manufacturing; production of three-dimensional objects directly from virtual models; rapid prototyping and highly decentralized production processes)			
Mobile technologies (all wireless technologies; fixed and on-the-go; real-time data capturing and accessibility, object tagging and internet-to-object communication)			
Cloud Computing (applications, platform and infrastructure solutions delivered as services over public or private networks)			
Advanced Analytics (Manufacturing specific Big Data- analyze operational processes and business performance, discover and explain inefficiencies and even predict future events)			
Machine-to-Machine (technologies allowing for the automated exchange of information between CPS through advanced embedded sensor and actuator applications technology)			
Community Platforms (the ‘classic’ social networks can be applied for easier on demand manufacturing and provide a wealth of data about customers)			

Advanced Robotics (Including Artificial Intelligence (AI) Technologies, advanced mechatronics, imitation of human body and behavior)			
Cyber and Property Security (guarantees data protection in enforced usage of communication technologies and platforms)			

Question 3:
In the future volatility of markets and thus volatility in customer request is predicted to increase. Production and assembly lines will need increasing flexibility and agility to produce lot sizes down to one in an efficient way. What do you think is the most agile way to produce? Please compare the flexibility of machines and human labor and explain how an ideal production process would look like.

Question 4:
"A better technology for a better price" – productivity and quality are key indicators of this motto. What do you think, and how can this motto be put into practice by using emerging technologies (e.g. CPS, Advanced Robotics, etc.) and human labor? Which tasks will employees have to perform in manufacturing and engineering? What is the ratio between human and machine performed tasks? (please estimate)

Future Tasks of Employees

Manufacturing labor	**Engineering labor**
Ratio - human/machine:	Ratio - human/machine:

Question 5:
If you think about the future tasks more in detail, where do you see critical tasks related to e.g. safety, health or environmental influences, that can only be performed by either human or machine? Please consider both manufacturing and engineering workforce.

Critical Tasks in Manufacturing

Human	Machine

Critical Tasks in Engineering

Human	Machine

Question 6:
If we think about the future work life in a digitized manufacturing environment, how would you anticipate the communication and collaboration could look like between employees and machines? Who will give the direction and which technologies will be used in human-to-machine communication?

Direction provided by:

Technologies:

Knowledge

The second section deals with the required skills, abilities and knowledge of future industrial workforce. Therefore, it is important to analyze the role of employees in future production processes and discuss solutions of how to get machines and human labor into socioeconomic balance. Whenever new technologies emerge, workers need to be trained to meet new requirements. Employee development can become time and cost consuming for employers and thus a great deal of thoughts must be given as soon as possible to meet the future skills needs of industrial workforce.

Question 7:
How important do you think are the following skills for future ***manufacturing*** *workforce? Please choose the five most important skills and rate them between 1 and 5. (1 refers to the most important skill. Please use every number only once)*

Skills	Importance	Reason
Chemistry		
Information and Communication Technologies (ICT)		
Computer coding		
Creativity techniques and entrepreneurial thinking		
Decision making		
Electronics		
Leadership		
Mathematics		
Mechanics		
Organizational planning		
Physics		
Presentation		
Problem solving		
Processing technologies		
Social behavior		
Added skills		
Materials		
Self-motivation		

Question 8:
*How important do you think are the following skills for future **engineering** workforce? Please choose the five most important skills and rate them between 1 and 5. (1 refers to the most important skill. Please use every number only once)*

Skills	Importance	Reason
Chemistry		
Information and Communication Technologies (ICT)		
Computer coding		
Creativity techniques and entrepreneurial thinking		
Decision making		
Electronics		
Leadership		
Mathematics		
Mechanics		
Organizational planning		
Physics		
Presentation		
Problem solving		
Processing technologies		
Social behavior		
Added skills		
Materials		
Self-motivation		

Question 9:
What needs to be done to guarantee a suitable knowledge base of future employees for upcoming technological challenges? What would you suggest in terms of formal education (e.g. schools and universities), non-formal or informal education (e.g. employee development methods) and vocational education solutions (e.g. apprenticeships, internships, trainees, etc.) related to manufacturing and engineering labor.

Formal Education

Manufacturing labor	Engineering labor

Non-formal / informal Education

Manufacturing labor	Engineering labor

Vocational Education

Manufacturing labor	Engineering labor

Globalization

On a global view of manufacturing industry, there is a big difference between more, less and least developed countries regarding human labor and technologies used. Regional differences in terms of technology trends and the requirements on production companies are evaluated in the last section.

Question 10:
On a global scale, which countries do you believe have the most capability in terms of know-how and resources to develop and implement technologies related to the fourth industrial revolution? Which of these countries do you believe have the highest amount of ongoing research activities related to these topics. Please choose five regions for each and rate them between 1 and 5. Please consider special countries with additional comments.

Region	Know-how	Resources	Research Activities
Arab States Region			
Asia and Pacific Region			
Australia / New Zealand			
Central Europe			
East and Southern Africa Region			
Eastern Europe and Central Asia Region			
Japan			
Latin American and the Caribbean Region			
Northern America			
West and Central Africa Region			

Question 11:
On a global scale, which countries do you believe have the highest need to develop and implement technologies related to the fourth industrial revolution to stay/become competitive? Why do you believe is it important to these countries? Can you refer it to a potential lack of skilled workforce or to stay competitive because of costs (labor, energy, etc.)? Please choose five regions at highest needs and rate them between 1 and 5. Please consider special countries with additional comments.

Region	Needs	Lack	Costs
Arab States Region			
Asia and Pacific Region			
Australia / New Zealand			
Central Europe			
East and Southern Africa Region			
Eastern Europe and Central Asia Region			
Japan			
Latin American and the Caribbean Region			
Northern America			
West and Central Africa Region			

Question 12:
In future, a social and economic balance between humans and machines must be guaranteed. How do you think is this possible in an era of digitization? How can manufacturing industry be socioeconomic factor, a bridge to create a stable political situation and prevent escalation over the worlds' nations?

Question 13:
Thank you very much for your valuable input on this topic. Last but not least, I want to ask you, if there is anything you want to add to this questionnaire? Please let me know if here are interesting topics related to the future industrial workforce in automotive industry 2035 and beyond.

Appendix 2: Questionnaire actual status

The interview consists of 10 semi-structured questions pertaining to three different topics. Interviews take approximately 45-60 minutes to conduct. Main content of the interviews is related to the case study project for the World Economic Forum – Global Agenda on the Future of Manufacturing. Thus, only a small number of questions are applicable for this thesis. Therefore, only the used questions are described within this chapter.

General Information

General information will be obtained from the interviewee. In this case, only the interviewees' name and plant location are important to compare the results.

Name:	
Location:	

Manufacturing Trends

The first section is to identify actual trends in manufacturing strategies and emerging technologies and evaluate their causes. It is important to be aware of these concepts and identify how they affect future work of human beings as it relates to manufacturing and engineering skills.

Question 1:
During the last decades, production strategies have changed from single unit production to mass production to mass customization. Also value and supply chains have changed from local (production) to local (market) to local to global till global to global business strategy concepts (offshoring of production and customization next to market). How do you expect will production strategies change?

Question 2:
On a global view, can you see differences in production strategies related to the discussed topics? What is you regional point of view and which challenges do you face in terms of the employment of skilled workforces in manufacturing and engineering?

Question 3:
If you think about the discussed strategies, how do you think could they be realized? Which new technologies are necessary to succeed and what would it mean to human labor?

Knowledge

The second section deals with the required skills, abilities and knowledge of manufacturing and engineering workforce. Therefore, the interviewees are asked to identify their employees' core skills.

Question 6:
*How would you describe the skills level of the actual **manufacturing** workforce at your plant? Please pick the 5 best skills of and rate them from 1 to 5 (1 refers the highest score, please use each number only one time).*

Skills	Importance	Reason
Chemistry		
Information and Communication Technologies (ICT)		
Computer coding		
Creativity techniques and entrepreneurial thinking		
Decision making		
Electronics		
Leadership		
Mathematics		
Mechanics		
Organizational planning		

Physics		
Presentation		
Problem solving		
Processing technologies		
Social behavior		
Added skills		
Materials		
Self-motivation		
Basic Science		
Operational Discipline		
Learning engagement		

Question 7:

*How would you describe the skills level of the actual **engineering** workforce at your plant? Please pick the 5 best skills of and rate them from 1 to 5 (1 refers the highest score, please use each number only one time).*

Skills	Importance	Reason
Chemistry		
Information and Communication Technologies (ICT)		
Computer coding		
Creativity techniques and entrepreneurial thinking		
Decision making		
Electronics		
Leadership		
Mathematics		
Mechanics		
Organizational planning		
Physics		
Presentation		

Problem solving		
Processing technologies		
Social behavior		
Added skills		
Materials		
Self-motivation		
Basic Science		
Operational Discipline		
Learning engagement		

Education

The automotive industry is exposed through inability in filling open positions and or replacement needs with skilled workforce for the future. To counteract this evolution, the educational systems have to fit the requirements of industry, as well as the desired needs of the future employees. Thus, the next questions aim to identify regional differences in education systems.

Question 9:
What is the actual education level of engineering and manufacturing workforce and where can you see differences? (Advantages, Disadvantages of the education systems) Please consider both native and foreign workforce.

Education of manufacturing workforce

native	foreign

Education of engineering workforce

native	foreign

Question 10:
Thank you very much for your valuable input on this topic. Last but not least, I want to ask you, if there is anything you want to add to this questionnaire? Please let me know if here are interesting topics related to the future industrial workforce in automotive industry 2035 and beyond.

Appendix 3: Definitions regions

Regional classification by UNFPA (United Nations Fund for Population Activities)[314]

Region Definition

Arab States Region
Algeria; Djibouti; Egypt; Iraq; Jordan; Lebanon; Libya; Morocco; Oman; Palestine; Somalia; Sudan; Syrian Arab Republic; Tunisia; Yemen; United Arabian Emirates

Asia and Pacific Region
Afghanistan; Bangladesh; Bhutan; Cambodia; China; Cook Islands; Fiji; India; Indonesia; Iran (Islamic Republic of); Kiribati; Korea, Democratic People's Republic of; Lao People's Democratic Republic; Malaysia; Maldives; Marshall Islands; Micronesia (Federated States of); Mongolia; Myanmar; Nauru; Nepal; Niue; Pakistan; Palau; Papua New Guinea; Philippines; Samoa; Solomon Islands; Sri Lanka; Thailand; Timor-Leste, Democratic Republic of; Tokelau; Tonga; Tuvalu; Vanuatu; Vietnam

Australia / New Zealand

Central Europe
Austria; (Andorra); Belgium; Croatia; Cyprus; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; Iceland; Ireland; Italy; Latvia; Liechtenstein; Lithuania; Luxembourg; Monaco; Montenegro; Netherlands; Norway; Poland; Portugal; Russia; San Marino; Slovakia; Slovenia; Spain; Sweden; Switzerland; United Kingdom; Vatican City (Holy See)

East and Southern Africa Region
Angola; Botswana; Burundi; Comoros; Congo, Democratic Republic of the; Eritrea; Ethiopia; Kenya; Lesotho; Madagascar; Malawi; Mauritius; Mozambique; Namibia; Rwanda; Seychelles; South Africa; South Sudan; Swaziland; Tanzania, United Republic of Uganda; Zambia; Zimbabwe

Eastern Europe and Central Asia Region
Albania; Armenia; Azerbaijan; Belarus; Bosnia and Herzegovina; Bulgaria; Georgia; Kazakhstan; Kyrgyzstan; Moldova, Republic of; Romania; Serbia; Tajikistan; The former Yugoslav Republic of Macedonia; Turkey; Turkmenistan; Ukraine.

Japan

Latin American and the Caribbean Region
Anguilla; Antigua and Barbuda; Argentina; Aruba; Bahamas; Barbados; Belize; Bermuda; Bolivia (Plurinational State of); Brazil; British Virgin Islands; Cayman Islands; Chile; Colombia; Costa Rica; Cuba; Dominica; Dominican Republic; Ecuador; El Salvador; Grenada; Guatemala; Guyana; Haiti; Honduras; Jamaica; Mexico; Montserrat; Netherlands Antilles; Nicaragua; Panama; Paraguay; Peru; Saint Kitts and Nevis; Saint Lucia; Saint Vincent and the Grenadines; Suriname; Trinidad and Tobago; Turks and Caicos Islands; Uruguay; Venezuela (Bolivarian Republic of)

Northern America
Canada; United States of America

West and Central Africa Region
Benin; Burkina Faso; Cameroon, Republic of; Cape Verde; Central African Republic; Chad; Congo, Republic of the; Côte d'Ivoire; Equatorial Guinea; Gabon; Gambia; Ghana; Guinea;

[314] Cf. UNFPA (2014), p. 118

Guinea-Bissau; Liberia; Mali; Mauritania; Niger; Nigeria; São Tomé and Príncipe; Senegal; Sierra Leone; Togo

Regions Overall

More developed countries:
regions comprise Europe, Northern America, Australia/New Zealand and Japan.

Less developed countries:
regions comprise all regions of Africa, Asia (except Japan), Latin America and the Caribbean plus Melanesia, Micronesia and Polynesia.

Least developed countries:
as defined by the United Nations General Assembly, consist of 48 countries. The group includes 48 countries - Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, Central African Republic, Chad, Comoros, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Haiti, Kiribati, Lao People's Democratic Republic, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Myanmar, Nepal, Niger, Rwanda, São Tomé and Príncipe, Senegal, Sierra Leone, Solomon Islands, Somalia, South Sudan, Sudan, Timor-Leste, Togo, Tuvalu, Uganda, United Republic of Tanzania, Vanuatu, Yemen and Zambia.

Appendix 4: Interviewees future developments

Expert	Name	Job Title	Company Name
1	Sachin Chitta	Founder & CEO	Kinema Systems
2	Eric Klein	Partner	Lemnos Labs
3	Lior Susan	General Partner	Formation 8
4	Dave Lyons	Co-Founder	Peloton Technology
5	-	-	-
6	-	-	CIE Automotive SA
7	-	-	-
8	Harro Wörner	Vice President Corporate Product- and Processdevelopment	Hirschvogel Automotive Group
9	Wolfgang Zitz	Vice President Contract Manufacturing	Magna Steyr Fahrzeugtechnik
10	Joachim Schuster	Manager Global Quality Initiatives	Magna Powertrain
11	Heinz Klampfl	Senior Manager, Component Process Development	Magna Powertrain
12	Martin Kiessner-Schatz	Director Manufacturing Strategy - Global	Magna Powertrain

Appendix 5: Final rating list for workers skills

Skills rating list original
Chemistry
Information and Communication Technologies (ICT)
Computer coding
Creativity techniques and entrepreneurial thinking
Decision making
Electronics
Leadership
Mathematics
Mechanics
Organizational planning
Physics
Presentation
Problem solving
Processing technologies
Social behavior
Additional actual skills
Materials
Self-motivation
Basic Science
Operational Discipline
Learning engagement
Additional future skills
Materials
Self-motivation

Appendix 6: Occupations at Magna Powertrain Plant Lannach

Code	Number of occupations within Plant Lannach	Job Title Magna Internal	Job Title O*NET SOC Taxonomy	Major Group	Minor Group	Broad Group
17-3029.09	39	Manufacturing Engineer	Manufacturing Production Technicians	Architecture and Engineering Occupations	Drafters, Engineering Technicians, and Mapping Technicians	Engineering Technicians, Except Drafters
17-2111.01	1	Safety Engineer	Industrial Safety and Health Engineers	Architecture and Engineering Occupations	Engineers	Industrial Engineers, Including Health and Safety
13-2011.02	1	Auditor	Auditors	Business and Financial Operations Occupations	Financial Specialists	Accountants and Auditors
49-9041.00	40	Maintenance Mechanics	Industrial Machinery Mechanics	Installation, Maintenance and Repair Occupations	Other Installation, Maintenance and Repair Occupations	Industrial Machinery Installation, Repair, and Maintenance Workers
49-2094.00	34	Maintenance Electric / Electronics	Electrical and Electronics Repairers, Commercial and Industrial Equipment	Installation, Maintenance and Repair Occupations	Electrical and Electronic Equipment Mechanics, Installers, and Repairers	Miscellaneous Electrical and Electronic Equipment Mechanics, Installers, and Repairers
49-9071.00	8	Facility Management	Maintenance and Repair Workers, General	Installation, Maintenance and Repair Occupations	Other Installation, Maintenance and Repair Occupations	Maintenance and Repair Workers, General
49-1011.00	2	Supervisor Maintenance	First-Line Supervisors of Mechanics, Installers, and Repairers	Installation, Maintenance and Repair Occupations	Supervisors of Installation, Maintenance and Repair Workers	First-Line Supervisors of Mechanics, Installers, and Repairers
11-1021.00	2	General Manager and Assistant General Manager	General and Operations Managers	Management Occupations	Top Executives	General and Operations Managers
11-3071.02	1	Distribution Manager	Storage and Distribution Managers	Management Occupations	Operations Specialities Managers	Transportation, Storage, and Distribution Managers
11-3071.03	1	Logistics Manager	Logistics Managers	Management Occupations	Operations Specialities Managers	Transportation, Storage, and Distribution Managers
11-3051.00	1	Production Manager	Industrial Production Manager	Management Occupations	Operations Specialities Managers	Industrial Production Managers

11-3051.01	1	Quality Engineer	Quality Control Systems Managers	Management Occupations	Operations Specialities Managers	Industrial Production Managers
11-1011.03	1	Sustainability Manager	Chief Sustainability Officers	Management Occupations	Top Executives	Chief Executives
51-4081.00	660	Operator Universally	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	Production Occupations	Metal Workers and Plastic Workers	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic
51-4191.00	86	Operator Hardening	Heat Treating Equipment Setters, Operators, and Tenders, Metal and Plastic	Production Occupations	Metal Workers and Plastic Workers	Miscellaneous Metal Workers and Plastic Workers
51-4072.00	73	Operator Casting	Molding, Coremaking, and Casting Machine Setters, Operators, and Tenders, Metal and Plastic	Production Occupations	Metal Workers and Plastic Workers	Molders and Molding Machine Setters, Operators, and Tenders, Metal and Plastic
51-1011.00	37	Teamleader Production	Second-Line Supervisors of Production and Operating Workers	Production Occupations	Supervisors of Production Workers	First-Line Supervisors of Production and Operating Workers
51-1011.00	15	Supervisor and Teamleader Production	First-Line Supervisors of Production and Operating Workers	Production Occupations	Supervisors of Production Workers	First-Line Supervisors of Production and Operating Workers
51-4111.00	8	Tool Maker	Tool and Die Makers	Production Occupations	Metal Workers and Plastic Workers	Tool and Die Makers
51-4194.00	4	Tool Grinder	Tool Grinders, Filers, and Sharpeners	Production Occupations	Metal Workers and Plastic Workers	Miscellaneous Metal Workers and Plastic Workers
53-7062.00	108	Distributors & Storage Stock…	Laborers and Freight, Stock, and Material Movers, Hand	Transporta-tion and Material Moving Occupations	Material Moving Workers	Laborers and Material Movers, Hand
53-7063.00	3	Machine Feeder	Machine Feeders and Offbearers	Transporta-tion and Material Moving Occupations	Material Moving Workers	Laborers and Material Movers, Hand
53-1021.00	2	Supervisor (Material Movement)	First-Line Supervisors of Helpers, Laborers, and Material Movers, Hand	Transporta-tion and Material Moving Occupations	Supervisors of Transporta-tion and Material Moving Workers	Hand

Appendix 7: Evaluation risk priority

Rating of Magna Powertrain Plant Lannach occupations according to Frey & Osborne (2013)

Code	RISK Rank	RISK Percentage	RISK Level
17-3029.09	221	0,24	LOW
17-2111.01	103	0,028	LOW
13-2011.02	589	0,94	HIGH
49-9041.00	374	0,67	MEDIUM
49-2094.00	277	0,41	MEDIUM
49-9071.00	352	0,64	MEDIUM
49-1011.00	2	0,003	LOW
11-1021.00	195	0,16	LOW
11-3071.02	328	0,59	MEDIUM
11-3071.03	328	0,59	MEDIUM
11-3051.00	107	0,03	LOW
11-3051.01	107	0,03	LOW
11-1011.03	70	0,015	LOW

51-4081.00	552	0,91	HIGH
51-4191.00	556	0,91	HIGH
51-4072.00	620	0,95	HIGH
51-1011.00	73	0,016	LOW
51-1011.00	73	0,016	LOW
51-4111.00	473	0,84	HIGH
51-4194.00	520	0,88	HIGH
53-7062.00	483	0,85	HIGH
53-7063.00	580	0,93	HIGH
53-1021.00	279	0,42	MEDIUM

Evaluation of Risk Level According to Frey & Osborne (2013)

Risk Level	**Min**	**Max**	**Occupations per Risk Level**	**Employees per Risk level**	**% of Employees per Risk Level**
LOW	0	0,3	9	99	8,78
MEDIUM	0,3	0,7	6	86	7,62
HIGH	0,7	1	8	943	83,60

Appendix 8: Skills rating detailed analysis

		Operator Universally		Distributors & Material Handlers	
		Importance	Characteristic	Importance	Characteristic
Skills	1	47520	Operation Monitoring	5076	Critical Thinking
	2	39600	Quality Control Analysis	5076	Coordination
	3	36960	Operation and Control	5076	Operation and Control
	4	34980	Critical Thinking	4752	Reading Comprehension
	5	34980	Monitoring	4752	Active Listening
Abilities	1	47520	Control Precision	7452	Static Strength
	2	43560	Problem Sensitivity	6804	Multilimb Coordination
	3	43560	Arm-Hand Steadiness	6804	Trunk Strength
	4	43560	Manual Dexterity	6048	Control Precision
	5	41580	Near Vision	5724	Oral Comprehension
Knowledge	1	48180	Mechanical	4860	English Language
	2	45540	Mathematics	4320	Mathematics
	3	41580	Production and Processing	3888	Transportation
	4	35640	Design	3564	Mechanical
	5	33660	Engineering and Technology	3348	Production and Processing

		Operator Casting		Operator Hardening	
		Importance	Characteristic	Importance	Characteristic
Skills	1	5418	Operation Monitoring	4818	Operation Monitoring
	2	5418	Operation and Control	4818	Operation and Control
	3	4816	Quality Control Analysis	4380	Monitoring
	4	4558	Active Listening	4088	Critical Thinking
	5	4300	Reading Comprehension	3869	Active Listening
Abilities	1	5418	Arm-Hand Steadiness	5037	Arm-Hand Steadiness
	2	5418	Manual Dexterity	5037	Multilimb Coordination
	3	5160	Control Precision	4599	Problem Sensitivity
	4	5160	Multilimb Coordination	4599	Selective Attention
	5	5160	Static Strength	4599	Manual Dexterity
Knowledge	1	5418	Production and Processing	3504	Production and Processing
	2	4214	Mechanical	3212	Computers and Electronics
	3	3268	Mathematics	3139	Mechanical
	4	1978	Public Safety and Security	3139	Chemistry
	5	1892	Engineering and Technology	2920	Public Safety and Security

		Maintenance Mechanics	
		Importance	**Characteristic**
Skills	**1**	3120	Equipment Maintenance
	2	3120	Repairing
	3	3000	Operation Monitoring
	4	2880	Troubleshooting
	5	2640	Operation and Control
Abilities	**1**	2880	Arm-Hand Steadiness
	2	2880	Manual Dexterity
	3	2760	Finger Dexterity
	4	2760	Control Precision
	5	2760	Multilimb Coordination
Knowledge	**1**	3600	Mechanical
	2	2680	Engineering and Technology
	3	2520	Production and Processing
	4	2440	Mathematics
	5	2440	English Language