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Professional Qualification in "Industrie 4.0": Building a Competency Model and Competency-Based Curriculum

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Summary

The intensive technological developments of recent years, such as sensors, cyber-physical systems, smart networks or automation, raise the new paradigm of Digital Transformation towards Industry 4.0. Industry 4.0 includes the transformation of work and production through autonomous and real-time systems that enable personalized, interconnected and smart products as well as services. Companies are forced to adapt their know-how and organizational structures towards this change in order to be successful on the market. Among many challenges that arise for companies in this paradigm, one of the most important ones is the employee qualification with the necessary competencies for working successfully in the transformed work environment. This educational challenge should be first addressed in the higher-level education in order to prepare students as employees of tomorrow with the competencies for Industry 4.0.

The goal of this work is to address this challenge by identifying the competencies for Industry 4.0 and develop a competency-based curriculum for universities based on them in order to prepare the students as future employees of Industry 4.0.

To achieve this goal, a literature analysis is conducted with the purpose of gathering competencies required for Industry 4.0. These results are evaluated and extended with focus group discussions. The evaluated competencies are presented in the form of a competency model covering three areas of relevance for Industry 4.0 that are Information Systems, Computer Science and Engineering. In a second step, a modular competency-based curriculum is developed by following a didactic six-step approach for competency-based curriculum development. Based on these competencies, learning objectives based on taxonomical criteria for each module were defined and principles of constructive alignment and experiential learning were applied. The curriculum addresses a broad spectrum of relevant Industry 4.0 topics and offers thus a collection of learning material for lecturers interested in teaching in this area at their universities. In order to demonstrate and evaluate the curriculum, a multi-dimensional evaluation approach is conducted on four different levels.

The main findings of the work include a detailed competency model for Industry 4.0 that covers the professional areas of Information Systems, Computer Science and Engineering as well as a competency-based curriculum for Industry 4.0 that covers a broad spectrum of relevant topics and was developed by following a structured approach. Furthermore, the work demonstrates how the applied approach can be used for competency-based curriculum development, as well as shows the application of design thinking for curriculum conceptualization and definition. Finally, an evaluation model for Information Systems curricula is developed. To validate the results, a multi-dimensional evaluation is applied, which offers implications about the curriculum application as well as possible topics for further research.

Zusammenfassung

Die technologischen Entwicklungen der letzten Jahre wie Sensoren, Cyber-Physical Systems, Smart Networks oder Automatisierung heben das neue Paradigma der Digitalen Transformation zu Industrie 4.0. Industrie 4.0 umfasst die Transformation von Arbeit und Produktion durch autonome und Echtzeitsysteme, die personalisierte, vernetzte und intelligente Produkte und Dienstleistungen ermöglichen. Unternehmen sind gezwungen, ihr Know-how und ihre Organisationsstrukturen für diesen Wandel anzupassen um am Markt erfolgreich zu bleiben. Die Qualifikation der Mitarbeiter mit den notwendigen Kompetenzen, um in der transformierten Arbeitsumgebung erfolgreich zu arbeiten, gehört zu den vielen Herausforderungen, die sich für Unternehmen in diesem Paradigma ergeben. Diese pädagogische Herausforderung sollte bereits früh in der universitären Ausbildung angegangen werden, um die Studierenden als Mitarbeiter von morgen mit den Kompetenzen für Industrie 4.0 auszubilden.

Ziel dieser Arbeit ist es, diese Herausforderung zu adressieren, indem die Kompetenzen für Industrie 4.0 identifiziert und darauf aufbauend ein kompetenzbasiertes Curriculum für Universitäten entwickelt wird, um die Studierenden als zukünftige Mitarbeiter für die Industrie 4.0 vorzubereiten.

Um dieses Ziel zu erreichen, wird eine Literaturanalyse durchgeführt, um die für Industrie 4.0 erforderlichen Kompetenzen zu erfassen. Diese Ergebnisse werden mit Fokusgruppendiskussionen evaluiert und erweitert. Die evaluierten Kompetenzen werden in Form eines Kompetenzmodells dargestellt, das drei für die Industrie 4.0 relevante Bereiche wie Informationssysteme, Informatik und Ingenieurwissenschaften abdeckt. In einem zweiten Schritt wird ein modulares kompetenzbasiertes Curriculum entwickelt, indem ein didaktisch sechsstufiger Ansatz zur kompetenzbasierten Curriculum-Entwicklung verfolgt wird. Basierend auf den Kompetenzen wurden Lernziele definiert, die auf taxonomischen Kriterien für jedes Modul basieren und Prinzipien der konstruktiven Ausrichtung und des erfahrungsorientierten Lernens anwenden. Das Curriculum adressiert ein breites Spektrum relevanter Industrie 4.0 Themen und bietet somit eine Sammlung von Lernmaterialien für Dozenten, die an Hochschulen in diesem Bereich unterrichten möchten. Um das Curriculum zu demonstrieren und zu evaluieren, wird ein mehrdimensionaler Evaluationsansatz auf vier verschiedenen Ebenen durchgeführt.

Zu den wichtigsten Erkenntnissen der Arbeit gehören ein detailliertes Kompetenzmodell für Industrie 4.0, welches die Berufsfelder Informationssysteme, Informatik und Ingenieurwissenschaften abdeckt, sowie ein kompetenzbasiertes Curriculum für Industrie 4.0, das ein breites Spektrum an relevanten Themen behandelt und basierend auf einem strukturiertem Ansatz entwickelt wurde. Darüber hinaus zeigt die Arbeit, wie der vorgestellte Ansatz für eine kompetenzbasierte Curriculum-Entwicklung genutzt werden kann, und zeigt die Anwendung von Design Thinking für die Konzeptualisierung und Definition von Curricula. Außerdem wird ein Evaluationsmodell für Curricula für Informationssysteme entwickelt. Um die Ergebnisse zu validieren, wird eine mehrdimensionale Evaluation angewendet, die Implikationen für die Anwendung des Curriculums sowie mögliche Themen für die weitere Forschung bietet.

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List of Abbreviations

CPS	Cyber-Physical Systems
CPPS	Cyber-Physical Production System
CS	Computer Science
DT	Digital Transformation
EQ	Evaluation Question
ERP	Enterprise Resource Planning
GBI	Global Bike Inc.
GBS	Global Bike Sharing
HCI	Human-Computer Interaction
HTML	Hypertext Markup Language
I4.0	Industrie 4.0
IoT	Internet of Things
IS	Information Systems
M2M	Machine-to-Machine
MOOCs	Massive Open Online Courses
RFID	Radio Frequency Identification
RQ	Research Question

1 Introduction

1.1 Motivation

"… Industry 4.0 will involve the technical integration of cyber physical systems into manufacturing and logistics and the use of the Internet of Things and Services in industrial processes. This will have implications for value creation, business models, downstream services and work organization."(Kagermann, Wahlster, & Helbig, 2013).

These developments bring disruptive changes in the everyday lives as well as transform whole industries (Downes & Nunes, 2013) including production and manufacturing by bringing the fourth industrial revolution, also known as "Industrie 4.0"/Industry 4.0.

Industry 4.0 affects whole business models, products, organizational structures and business processes (BMAS, 2015; Gebhardt, Grimm, & Neugebauer, 2015; Zinn, 2015). These changes can be observed in the transformation that certain branches are undergoing as well as in the rising demand for internet based services. For example, Television broadcasters are losing viewers, while online streaming services as Netflix, Amazon or HBO have developed whole new services and revenue streams by reaching a high number of subscribers. The whole model of work organization transforms due to the disruptive nature of these technologies as well as modified structures for communication and collaboration (BMAS, 2015; Gebhardt et al., 2015; Zinn, 2015). This disruption in the businesses transforms the work environment (acatech, Fraunhofer IML, & equeo GmbH, 2016) and makes certain job profiles obsolete, while new tasks and duties and consequently new jobs arise.

Due to the transformation in the work environment and job profiles, Industry 4.0 requires employees with a new set of competencies (acatech et al., 2016; Kagermann et al., 2013). While operational workforce will be partly substituted with machines and artificial intelligence, the need for qualified university graduates who design these machines and take strategical decisions in Industry 4.0 will rise. Employee qualification with the necessary competencies is one of the key challenges for Industry 4.0 (Kagermann et al., 2013). It is crucial to prepare the workforce of tomorrow for the disruption that the technology and business world are undergoing (Jaschke, 2014; Richert et al., 2016; Richter, Heinrich, Stocker, & Unzeitig, 2015) by putting a special focus on the university graduates that will be tomorrow's workforce. Businesses need to extend their competencies in order to optimize their structures for the transformation towards Industry 4.0 (McKinsey, 2015). Therefore, two challenges arise.

It is important to know the competencies needed for Industry 4.0, especially for university graduates. The main requirement for implementing Industry 4.0 is a wide range of competencies (Smit, Kreutzer, Moeller, & Carlberg, 2016), therefore a clear definition of the competencies for Industry 4.0 is needed (Jaschke, 2014; Richert et al., 2016; Richter et al., 2015). In this context some research and contributions have already been made. After a literature analysis, Erol, Jäger, Hold, and Sihn (2016) proposes a set of competencies for Industry 4.0. acatech et al. (2016) also made a similar contribution by analyzing German companies and proposing competencies divided in two areas, competencies that the companies should master and competencies that the employees should adapt. Other authors as Gebhardt et al. (2015), Guo (2015), Stocker, Brandl, Michalczuk, and Rosenberger (2014), Windelband (2014) and Richter et al. (2015) also analyze work in Industry 4.0 by mentioning competencies that will become relevant.

However, the mentioned competencies are rather generic and a structured competency model for Industry 4.0 focusing on jobs that require an academic education is still missing. In Industry 4.0, work profiles that require an academic education will earn on significance, while labor workforce will be mostly replaced by automated processes. Therefore, competency models focused on different aspects of the academic education should be defined.

Defining the competencies is the first step towards preparing the workforce of tomorrow for Industry 4.0. The further challenge consists in preparing students and workforce in adapting these competencies through dedicated teaching concepts and curricula (Richter et al., 2015). One of the top priorities of education provisioning for succeeding in Industry 4.0 lies in developing competency-based curricula and teaching concepts in universities. Curricula for this purpose are still missing. Most of the offered curricula are related to special aspects of Industry 4.0 (Erol et al., 2016), e.g. by focusing on cyber physical systems, security, sensors etc. Industry 4.0 however changes the working environment in various aspects. Apart from the technologies, strategical, managerial and process related competencies are also an important aspect of Industry 4.0 that should as well be addressed in education (Löffler et al., 2017; Prifti, et al., 2017). Therefore, there is a need for competency-based curricula for preparing the workforce of tomorrow with the competencies for Industry 4.0.

This thesis aims in addressing both these challenges. First of all, competencies for Industry 4.0 are defined and a competency model for Industry 4.0 is developed by focusing on areas as Information Systems (IS), Computer Science (CS) and Engineering that require and academic education and will play a crucial role in Industry 4.0. In a second step a competency-based curriculum that teaches the defined competencies is developed in a six-phase didactic approach for curriculum development. This curriculum is evaluated with education experts as well as students to prove its validity. In this way this thesis makes a contribution to two important challenges affecting industry and businesses nowadays.

1.2 Target Group

In Industry 4.0, work profiles that require an academic education will earn in significance, while labor workforce will be mostly replaced by automated processes. In this context there are many profiles and jobs that require academic education and will be affected by Industry 4.0.

In Industry 4.0 production machines will play a central role, which requires therefore adjusted job profiles for Engineers. IT is responsible for designing suitable architectures and programming these machines, which requires new competencies for Computer Scientists. This transformation in production will be accompanied with “new business processes as well as new ways of communication and collaboration that will lead to adjusted or even new IT processes and structures, but also to a different way of managing people, which requires customized competency profiles for Information System (IS) professionals" (Prifti, Knigge, Kienegger, et al., 2017).

This thesis will focus on these three areas: IS, CS and Engineering by proposing a competency model for professions in these areas and developing a curriculum with contents that can be applied in these areas of education.

It should not be understood that these are the only areas affected by Industry 4.0. Almost every profession will be affected in some way and therefore competencies for each profession should be defined. Architects will be required to design working spaces and factories that address a whole new kind of machines and a new way of work organization, doctors will be required to adapt to the new requirements of work that might lead to different health issues for the employees, teachers and professors will be required to acquire competencies in order to be able to teach the required contents and so on.

However it is not possible to address each and every profession or area of studies. Therefore this thesis has a clear target group by focusing on work profiles that require an academic education in the areas of IS, CS and Engineering. This target group will be addressed throughout the whole thesis.

1.3 Research Design

The structure of this thesis follows the design science principles of Hevner, March, Park, and Ram (2004). The aim of this thesis is to define competencies that IS, CS, and Engineering graduates should adopt in order to be qualified for job positions in the context of Industry 4.0. Based on these competencies, a competency-based curriculum for Industry 4.0 is developed and afterwards evaluated. In a first step the knowledge base is founded by using literature review and focus groups to define the competencies for Industry 4.0. The results are used for developing a competency model. The second step delivers an artefact that includes a competency-based curriculum for Industry 4.0. The curriculum delivers a teaching concept in the area of Industry 4.0 and addresses the competencies that were discovered in the knowledge base. In the third step the artefact is evaluated and further improved with feedback from the evaluation by conducting the last step of Hevner et al. (2004)'s approach.

The thesis is structured in three research questions (RQ):

RQ1: *What competencies are critical for job positions that require higher education for effectively and efficiently performing in Industry 4.0?*

This research question aims in delivering a behavioral based competency model for Industry 4.0 that has three different variants: IS, CS and Engineering and builds the theoretical basis for this thesis as recommended by Hevner et al. (2004). For the purpose of this study the definition of Bartram, Robertson, and Callinan (2002), who defines competencies as: "sets of behaviors that are instrumental in the delivery of desired results or outcomes" is used. A competency model consists of desired competencies for a certain task and may also include a description of single competencies as well as a relationship between them (Lucia & Lepsinger, 1999). Industry 4.0 competencies are extracted from the literature by following the recommendations of Webster and Watson (2002). Since the topic is new, only little research exists. Therefore by following the recommendations of Levy and Ellis (2006), practical articles, white papers and reports that propose competencies for Industry 4.0 were also considered. For evaluating and extending the literature review, focus group interviews as recommended by Krueger and Casey (2014) were conducted in order to gain practical insights on the topic. A total of four focus groups with 18 - 25 participants each were conducted. The participants were lecturers with various years of experience in university teaching and education in the areas of IS, CS, Economics and Engineering. This target group was addressed since lecturers have a general understanding of competencies and apply competency targeted teaching. Most of them also were involved in research and therefore aware of Industry 4.0, its relevance and the importance of building up competencies for the future employees. The Critical Incident Technique (Flanagan, 1954; Koch, Stroebel, Kici, & Wesrhoff, 2009) was applied for the focus group guidelines. After extracting and synthetizing the competencies from the literature and focus groups the SHL Universal Competency Framework (UCF)[1] offered from CEB Inc.[2] was used for developing the Industry 4.0 competency model for IS, CS and Engineering. The SHL UCF is chosen since it is based on different competency approaches from research and practice; offers a behavioral approach for competency modeling that better serve the results and purpose of this thesis and offers a framework that can be used to develop competency models, which represent a descriptive and simplified view of the competencies as a specific phenomenon to be analyzed.

As a result, a competency model that has three variants, focusing on IS, CS, and Engineering graduates, is delivered. It defines the competencies that each of these groups should bring to efficiently and successfully work in Industry 4.0. The competencies are derived from the literature and focus groups with lecturers that teach in universities.

RQ2: *Which didactic concepts, contents and hands-on experiences are required for a competency-based Industry 4.0 curriculum?*

The second research question delivers a competency-based curriculum for Industry 4.0 including theoretical and practical teaching components. A curriculum can be defined as a collection of documents aiming in delivering a structured series of learning experiences that includes theoretical and practical content to deliver predefined competencies to the learner. The six phase approach recommended from Schaper, Reis, Wildt, Horvath, and Bender (2012) for competency-based curriculum development that includes content and conceptual as well as organizational steps is followed. Schaper et al. (2012) offer an approach for developing a competency-based course of studies. They describe not only content and conceptual steps for the development, but also organizational steps, since the development of a course of studies is also connected with the faculty administrative staff. This approach was adapted in this thesis for the

1 SHL Universal Competency Framework (UCF) presents a state-of-the-art perspective on competencies and is used worldwide from well-known companies as e.g. Coca Cola ((Bartram, 2011)). It is offered by CEB Inc ((Bartram, 2005)).

2 CEB Inc. is a global best practice and insights technology company providing services to businesses worldwide.

development of a single curriculum. For this purpose the organizational steps are not needed and only the conceptual steps for the curriculum development were applied. These steps include:

- Step 1: Determination of qualification objectives or competencies and definition of competency profiles;
- Step 2: Definition of the learning outcomes for the curriculum based on taxonomical criteria and systematics;
- Step 3: Planning of the single learning units for each curriculum and defining the learning outcomes for each unit as well as conceptualizing of the single learning units and teaching methods for each unit
- Step 4: Developing of the learning unit content by including the theoretical and practical part;
- Step 5: Developing accompanying measures for the implementation of the curriculum;
- Step 6: Developing evaluation mechanisms for the unit in order to measure if the intended learning outcomes were achieved (Schaper et al., 2012).

Further recommendations from Biggs and Tang (2011) for curriculum development by applying the constructive alignment concept and shifting the focus from the teacher to the learner were used.

By following the recommendations of Schaper et al. (2012) an independent learning unit for each of the curriculum topics with concrete and pre-defined content and learning outcomes was defined. Each learning unit includes theory as well as practical and interactive exercises.

RQ3: *What are the effects and results of the curriculum application on the target group?*

In the last research question the proposed curriculum modules are evaluated and further improved by building the last step of design science as suggested by Hevner et al. (2004). The evaluation, revision and final refinement of the curriculum is also the last phase of the six phase approach recommended from Schaper et al. (2012) for competency-based curriculum development. Therefore a multidimensional evaluation is conducted. As recommended by Schaper et al. (2012), an evaluation model is provided that lecturers can apply in their courses for evaluating the applied curriculum. Furthermore the curriculum itself is evaluated in three steps. As Schaper et al. (2012) recommend a pilot evaluation is conducted first, for gathering feedback before releasing the curriculum. After the curriculum was released a holistic evaluation of the curriculum and curriculum concept was conducted. In both these evaluations by following the principles of data triangulation recommended by Denzin (1978) qualitative and quantitative data is gathered by conducting discussions with experts as well as surveys. In order to also evaluate the content of the curriculum and the whole competency-based approach, three field tests were conducted with students. The students had to feel-in some self-assessment questions as recommended by Schaper et al. (2012) before and after the field test. Each question was connected with one competency and learning outcome of the unit being evaluated. The findings of these evaluation steps were used to further refine and improve the evaluated results with regards to Hevner et al. (2004).

1.4 Structure of this Thesis

Based on the defined research questions and research methods the structure of this thesis is as described below.

1. Introduction: In the first chapter of this thesis an introduction and motivation of the topic is presented. This is followed by the definition of the target group that that lies in the focus of the whole thesis. In the next step the research questions of the thesis and the applied research methods and approaches are presented followed by an overview of the structure of the thesis and a clarification of the project context in which this thesis was developed.
2. Definitions and Theoretical Foundation: In the second chapter the main concepts and terminology that are central for the thesis are presented in detail. Based on it for each of the terms a definition in the context of this thesis is conducted. In this way a common understanding and theoretical foundation is set for this work.
3. A Competency Model for Industry 4.0: The third chapter presents the findings of the first research question as presented in the section above. After an introduction to the topic and its relevance the applied research methods are presented and the followed approach is described. Afterwards the developed competency model is presented and the competencies are described in detail.
4. A Competency-based Curriculum for Industry 4.0: The fourth chapter gives answer to the second research question as presented above. After a motivation of the relevance of the contribution of this chapter the applied method is presented in detail followed by a presentation of an overview of the curriculum. As an example of the content two modules of different nature are presented in detail.
5. Curriculum Evaluation: The fifth chapter presents the results of the third research question by conducting an evaluation of the presented results. After explaining the relevance of the evaluation and the followed approach, four evaluation steps, conducted in the context of this thesis are presented.
6. Summary: The work is concluded with a summary of the results and presentation of topics for further research.

The structure is represented graphically in Figure 1.

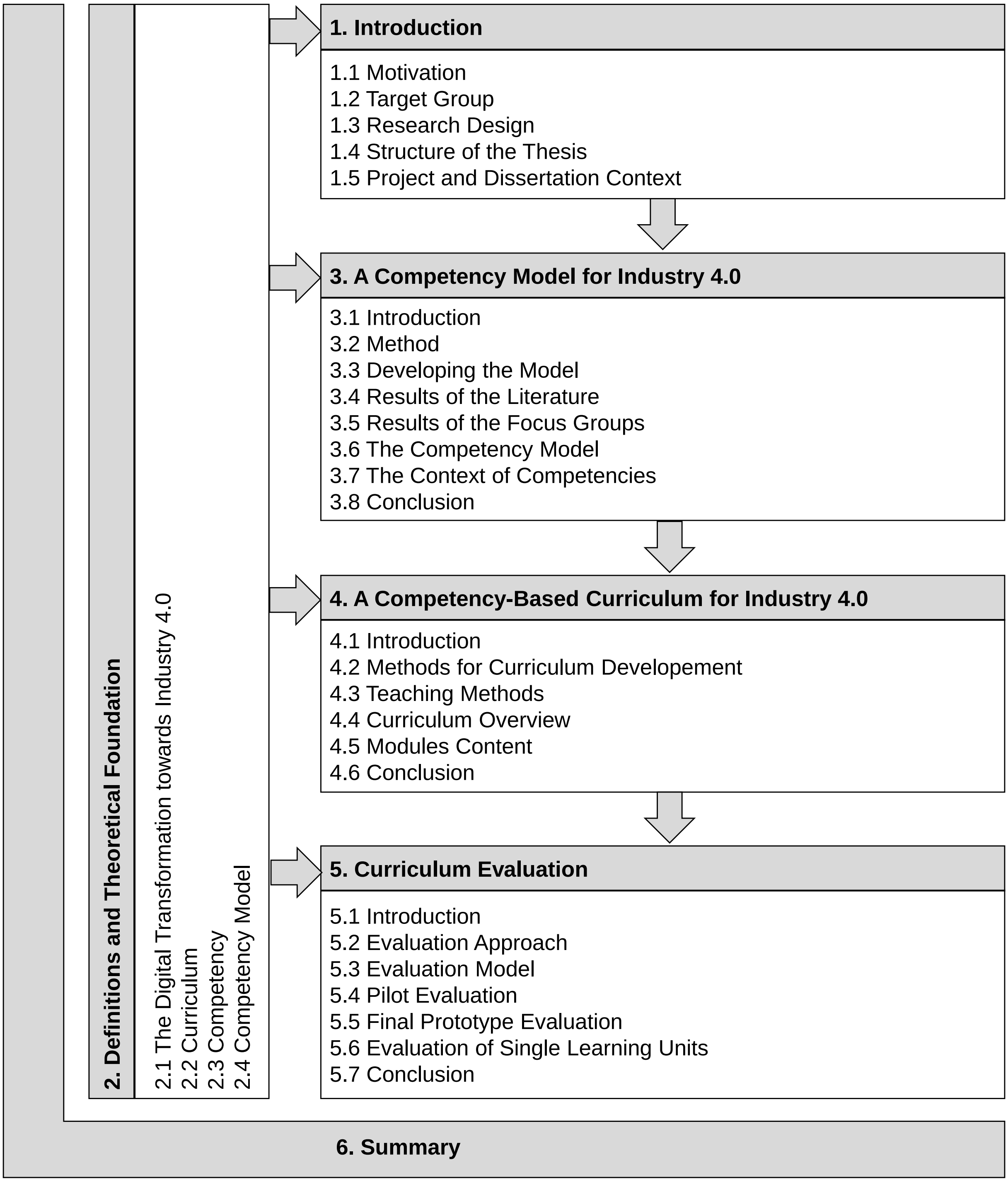

Figure 1: Structure of the Thesis
(Source: Own Representation)

1.5 Project and Dissertation Context

This dissertation is written in the context of a curriculum development project at the SAP University Competence Center (UCC) Munich[3]. The SAP UCC is an education as a service providing institution, specialized in hosting and providing SAP systems for teaching and research purposes. For the hosted systems, the SAP UCC also provides curricula and additional services (Prifti, Knigge, Löffler, Hecht, et al., 2017). In this context SAP UCC defined a project in developing a curriculum for the digital transformation towards Industry 4.0. This curriculum was developed from a team of employees from the UCC Munich where the author of this thesis was part of the team and responsible for developing a part of the curriculum content.

This dissertation was developed in the context of this curriculum development project as a conjoint research project with Marlene Knigge, where each of the researchers addresses a different aspect.

In this thesis the focus is primary on education that is conducted in universities by extracting competencies in university context and also develop and evaluate parts of the curriculum in this context. Marlene Knigge focuses on secondary education and addresses professional development and training for people that are already working by extracting competencies and developing and evaluating the curriculum in companies' context.

The other team members were involved in the content development of other modules that are not part of this thesis. The differentiation with the dissertation of Marlene Knigge as well as of the content developed by other team members is presented in Figure 2. As part of this thesis are only considered the modules that were developed directly from the author of the thesis, which are presented in continuous lines in the graphic below[4].

[3] http://sap-ucc.com/ (see also (Prifti, Knigge, Löffler, Hecht, et al., 2017))

[4] During the time of this work, various results were published in conferences and journals. Parts of these results are also used and referred in the thesis. A list of all the publications is therefore provided in Attachment A: List of Publications.

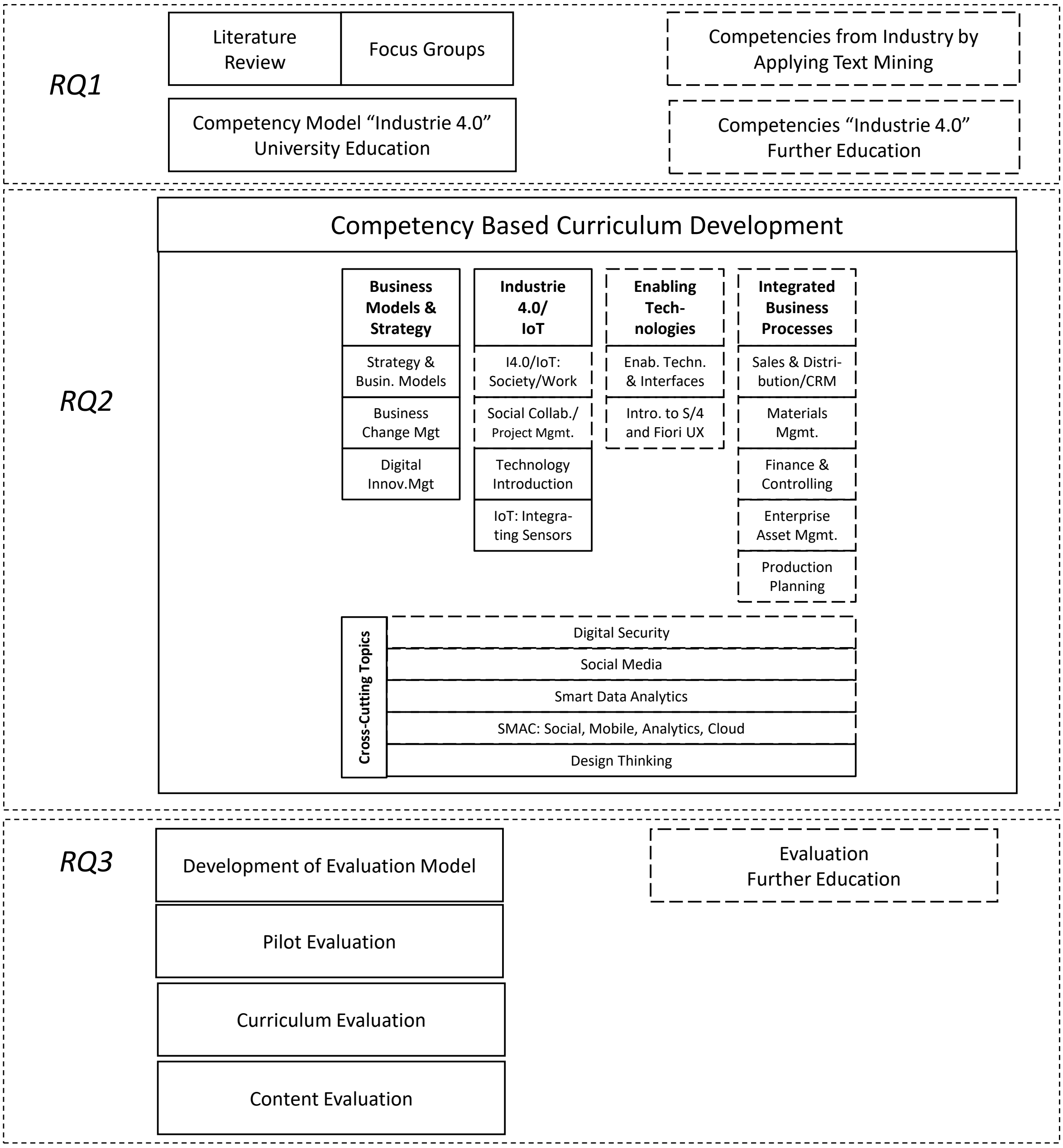

Figure 2: Curriculum Development Framework
(Source: Own Representation)

2 Definitions and Theoretical Foundation

2.1 The Digital Transformation towards Industry 4.0

Technology increasingly affects the business world (Brynjolfsson & McAfee, 2012). Disk drive capacity (Walter, 2005) and network bandwidth (Zhao, Fischer, Aker, & Rigby, 2013) are improving over time. The costs for computational power, storage capacity and network bandwidth are continuously decreasing, which drives the so called Digital Transformation (Hoberg, Krcmar, Oswald, & Welz, 2015)

Companies in almost all industrial sectors have conducted numerous initiatives to explore new digital technologies and to exploit their benefits (Matt, Hess, & Benlian, 2015). Therefore, the "Digital Transformation" appears in strategic visions across companies in all industrial sectors (Denecken, 2014).

The term "Digital Transformation" has various understandings (Bloching et al., 2015). It is often mentioned together with digitalization or Industry 4.0, which are considered as actual trends. Deloitte (2016) mentions the digitalization as a megatrend of nowadays. Roland Berger, tried to define Digital Transformation in a study, commissioned by the Bundesverband der deutschen Industrie e.V. (BDI), the Federation of German Industries, as:

[…] comprehensive networking among all economic sectors and stakeholder adaption towards the new circumstances of the digital economy. Decisions in network systems include data exchange and analysis, calculation and evaluation of options and the initiation of actions and consequences (Bloching et al., 2015).

However, there is not a common understanding about the digitalization or digital transformation, nor its differentiation from Industry 4.0. Often it is considered as the digitalization of processes with the help of IT. BMWi (2015) goes further in the concept and considers not simply the transformation in the industry but also the social transformation through the digitalization as part of the Digital Transformation towards Industry 4.0. Hoberg et al. (2015) support this thesis by considering digital transformation projects characterized with „[…] high social complexity, structural rigidity, and procedural ambiguity."

In the context of this work, digitalization and the Digital Transformation are considered as synonyms. The digital transformation is the holistic interconnection of economy and society where intercommunicating networks arise. Data is gathered from the arising networks and analyzed in order to exploit new possibilities. Processes are digitalized and therefore new business models arise (Deloitte, 2016; Kagermann et al., 2013).

For the industry, the Digital Transformation means a radical transformation of the production and value chain network, characterized through autonomous and interconnected systems. This presents many chances and brings new challenges (acatech et al., 2016). The application of the Digital Transformation in the industry is considered as Industry 4.0 (Hirsch-Kreinsen, Ittermann, & Niehaus, 2015). In summary the terms digitalization and Digital Transformation are holistic terms for the transformation occurring due to the application of technology. This transformation has an impact on the society, economy and industry. The application of the digitalization in the production and industry is considered as Industry 4.0.

2.1.1 Definition Industry 4.0

Industry 4.0 or Industrie 4.0, known as the fourth industrial revolution, is one of the ten future projects of the High-Tech Strategy 2020 action plan that was introduced for the first time by the Federal Government at the „Hannover-Messe" in 2011 (Kagermann, Lukas, & Wahlster, 2011). Since then there is much discussion regarding the topic.

To achieve Industry 4.0 innovative communication technologies though machines, humans, and products will be established (Gebhardt et al., 2015; Kaufmann, 2015; Roth, 2016). A communication of the virtual world with the physical products and independent machine learning are fundamental in Industry 4.0 (Gebhardt et al., 2015). The aim is a more efficient, more flexible and individual production, which can be achieved through decentralized controls of production and also through completely digitally controlled or even self-organized value chains (Brühl, 2015; Gebhardt et al., 2015). This creates new forms of cooperation, due to the changing of value-added processes and the reorganized division of labor (Brühl, 2015).

This means that Industry 4.0 includes many components. The basic components for Industry 4.0 are the cyber physical systems (CPS) that connect physical machines with virtual software components (Geisberger & Broy, 2012). The CPS communicate with each other through machine-to-machine (M2M) communication, which makes independent communicating systems possible. This empowers the automation of processes and production (Lee, Bagheri, & Kao, 2015). However, production is not the only area where Industry 4.0 has an influence. Challenges of the today's world as mobility, health, climate change or energy are some of the main areas influenced by Industry 4.0 (Kagermann et al., 2013).

Through the automation, a big amount of data is generated the so-called big data. This data can be analyzed through algorithms in order to make sense of them. (Zikopoulos & Eaton, 2011). Based on the analyses of this data, predictions can be made in Industry 4.0. By combining data from different sources, it can be e.g. calculated if it is possible to individualize a serial production to a reasonable price (Kaufmann, 2015). Another scenario is predictive maintenance, where sensors are combined to predict if a machine is going to fail. In this case measures to repair it are taken upfront and still stand in production is avoided. If big data is used to generate value for a company, it is also called smart data (BMWi, 2016).

A detailed definition of the term Industry 4.0 was released by the i4.0 (2015) publication, which defined Industry 4.0 as:

„[...] the fourth industrial revolution, a new level of organization and management of value-chain over the life cycle of products. This cycle is based on increasingly individualized customer wishes and it ranges from the product idea, the ordering, from the developing and the manufacturing, as well as to the delivery of a product to the end customer through to recycling, by

including also related services. The basis is the availability of all relevant information in real-time through the networking of all instances that are involved in the value and the ability to derive the optimal value stream from the data at any time. By connecting people, objects and systems, real-time optimized and self-organizing company-wide value networks arise that can be optimized according to different criteria such as cost, availability and resource consumption."[5] (i4.0, 2015)

Obermaier (2016) used the above definition to develop a concise concept that favored the business aspect:

"„Industry 4.0" describes a form, that is characterized by digitization, automation and networking of all actors involved in the value and it affects processes, products or business models of industrial enterprises."[6] (Obermaier, 2016)

Another definition by Hermann, Pentek, and Otto (2016), that aims at the technologies as well as the components of Industry 4.0 is described as follows:

„ […] can be defined as a collective term for technologies and concepts of a value chain organization which creates together Cyber-Physical Systems (CPS), Internet of Things, Internet of Services, Internet of People (IoP), and Internet of Energy."(Hermann et al., 2016).

According to Kagermann et al. (2013):

"[..] Industry 4.0 will involve the technical integration of CPS into manufacturing and logistics and the use of the Internet of Things and Services in industrial processes. This will have implications for value creation, business models, downstream services and work organization." (Kagermann et al., 2013)

The last introduced definition of Prof. Wilfried Sihn – TU Wien defines Industry 4.0 as

[5] "[…] die viertel industrielle Revolution, einer neuen Stufe der Organisation und Steuerung der gesamten Wertschöpfungskette über den Lebenszyklus von Produkten. Dieser Zyklus orientiert sich an zunehmend individualisierten Kundenwünschen und erstreckt sich von der Idee, dem Auftrag über die Entwicklung und Fertigung, die Auslieferung eines Produkts an den Endkunden bis hin zum Recycling, einschließlich der damit verbundenen Dienstleistungen. Basis ist die Verfügbarkeit aller relevanten Informationen in Echtzeit durch Vernetzung aller an der Wertschöpfung beteiligten Instanzen sowie die Fähigkeit, aus den Daten den zu jedem Zeitpunkt optimalen Wertschöpfungsfluss abzuleiten. Durch die Verbindung von Menschen, Objekten und Systemen entstehen dynamische, echtzeitoptimierte und selbst organisierende unternehmensübergreifende Wertschöpfungsnetzwerke, die sich nach unterschiedlichen Kriterien wie bspw. Kosten, Verfügbarkeit und Ressourcenverbrauch optimieren lasse." (BMWi, 2016)

[6] "„Industrie 4.0" beschreibt eine Form industrieller Wertschöpfung, die durch Digitalisierung, Automatisierung sowie Vernetzung aller an der Wertschöpfung beteiligten Akteure charakterisiert ist und auf Prozesse, Produkte oder Geschäftsmodelle von Industriebetrieben einwirkt." (Obermaier, 2016)

„[…] the integration of the latest information and communication technologies (ICT) with traditional physical products and processes, which allows new business models to arise and new markets to develop“[7] (Erol et al., 2016)

“In summary, Industry 4.0 is the fourth industrial revolution, its aim is a more efficient, flexible and individual production achieved through decentralized controls of production and completely digitally controlled or even self-organized value chains and where automation, real-time and sensor technologies play a crucial role.” (Prifti, Knigge, Kienegger, et al., 2017)

2.1.2 History of Industry 4.0

Industry 4.0 is considered the fourth industrial revolution and therefore a change in the paradigm (Windelband, 2014) that has become a buzzword in a short period of time.

As it is shown in the Figure 3, the first industrial revolution started in the year 1750. This industrialization in textile, iron, and steel industries became possible by the advent of water and steam engines (Lüder, 2014; Roth, 2016). The improvement in manufacturing led in improvements in transportation systems as well as in the production of basic goods as food and clothing. This led to an increase of the population (Lüder, 2014). This change divided the population into two classes: the factory workers and the factory owners. Simultaneously, more and more people moved from the countryside to the cities looking for work (Lüder, 2014).

In the year 1870 started the second industrial revolution , which was characterized by the mass production based on the division of labor and realized with the help of electrical energy and conveyor belts (Kaufmann, 2015; Lüder, 2014; Roth, 2016). In this time electric engines were developed. Using oil as fuel for the industry and mobility led to a new milestone and a new development towards the progression in chemical, electrical, engineering and automotive industries (Lüder, 2014).

The third industrial revolution arose because of the economic miracle of the early 60s that occurred in Germany and many other European countries. It was dominated by electronics, and more recently by the information and communication technology (ICT) for automation of production (Kaufmann, 2015; Lüder, 2014; Roth, 2016). Companies assign great value to quality and individuality. Additionally, ICT as well as the internet kicked off an unprecedented availability of knowledge.

Since 2011, Industry 4.0, which has been supported by the „Deutsche Industrie 4.0 Initiative“, has been called the upcoming fourth industrial revolution in Germany, entailing encompassing networked and communicating systems whether in production or in ICT (Kaufmann, 2015;

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[7] “[...] die Integration modernster Informations- und Kommunikationstechnologien (IKT) mit klassischen physischen Produkten und Prozessen, durch die neue Geschäftsmodelle entstehen und neue Märkte erschlossen werden“ (Erol et al., 2016)

Lüder, 2014; Roth, 2016). With the help of the latest internet technologies, the approach of an intelligent factory should be achievable (Lüder, 2014; Roth, 2016; Siepmann & Graef, 2016).

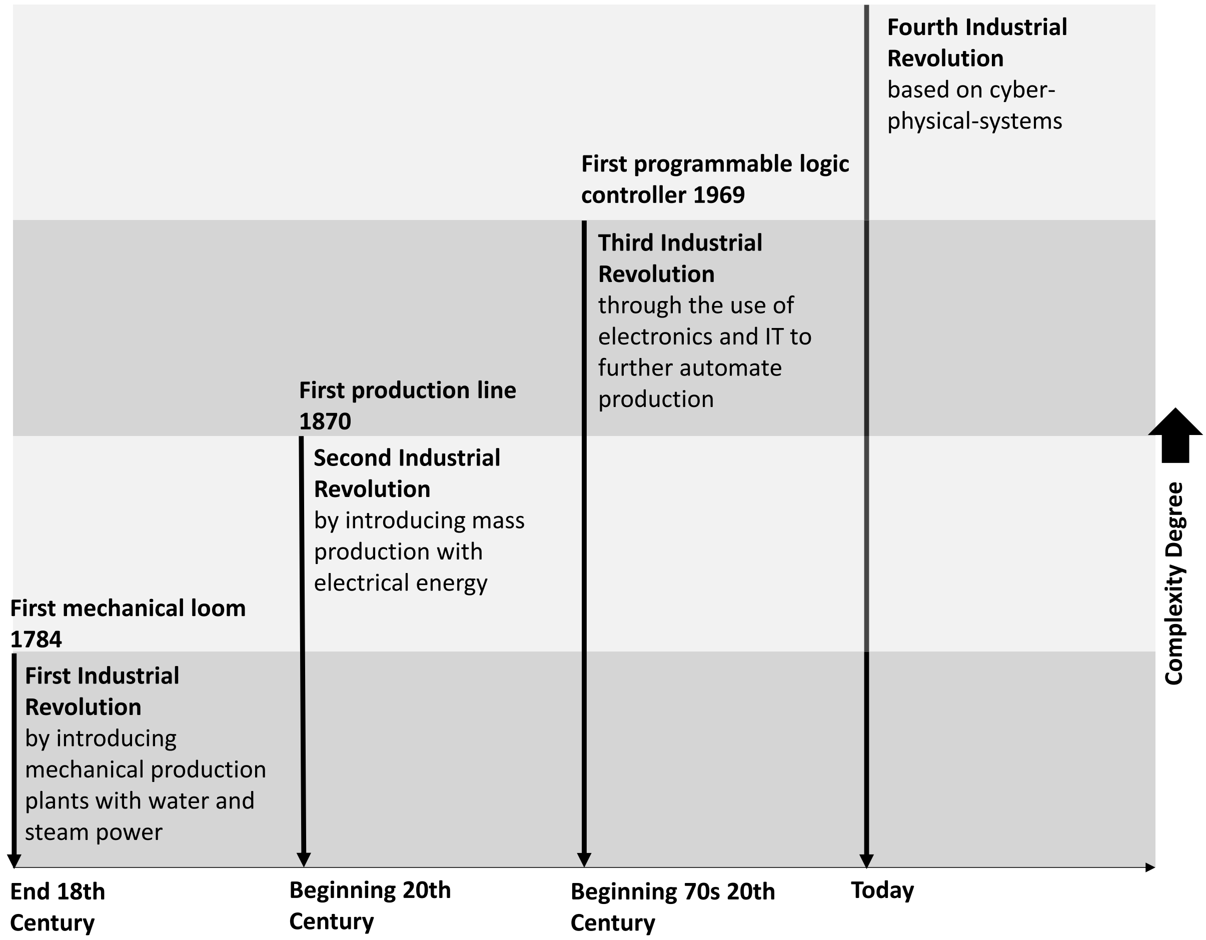

Figure 3: Overview of the Fourth Industrial Revolution (Source: Own Representation based on RobIN4.0 (2016))

2.1.3 Components Industry 4.0

Industry 4.0 comes as a new paradigm. It is however, a combination of technologies that make holistic and many-dimensional solutions possible. Therefore, in this chapter some of the components and developments that made Industry 4.0 possible will be explained.

2.1.3.1 Cyber-Physical Systems

The Cyber-Physical Systems (CPS) are one of the fundamental components of the Industry 4.0 (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014; Roth, 2016). The elements of the CPS are combined together in forming intelligent networks (Roth, 2016). Aichele and Doleski (2014) define it as *"[...] the network of informatics and software engineering components with mechanical and electronic parts that communicates via data infrastructure such as internet"*[8] ((Aichele & Doleski, 2014) found in (Kaufmann, 2015)). Kagermann et al. (2013) refer to CPS as smart products in Industry 4.0.

Broy (2010) mentions that CPS target the connection of embedded systems with the possibilities of worldwide networks. They can be understood as physical products e.g. device, building, transport, production plant and logistics' components that can communicate by means of embedded systems using the internet (Brühl, 2015; Lüder, 2014). Examples of CPS applications can be found in numerous areas, including: smart transportation, smart buildings, advanced manufacturing, precision agriculture, etc. (Cimpeanu et al., 2015).

Embedded Systems are programmable (micro-) computers with storage capability, which create the technical requirements for Industry 4.0 (Brühl, 2015). They are attached to physical systems and each of these physical objects get in this way a unique identity. Therefore the physical objects become smart (Geisberger & Broy, 2012; Kaufmann, 2015).

In a study from Geisberger and Broy (2012), the characteristics and upcoming challenges of CPS are listed, by defining them as an open socio-technical system with the following capabilities:

- Data collection through sensors,
- Response to physical processes by means of actuators,
- Evaluation and storage of data,
- Using the data to make the decisions,
- Connection of systems locally and globally,
- Use of data and services, which are available worldwide and
- Having different multimodal Human-Machine Interfaces. (Geisberger & Broy, 2012)

Furthermore, acatech et al. (2016) describes five dimensions on the basis of these capabilities. These five dimensions determine the following "[…] evolutionary and revolutionary features of Cyber-Physical Systems" (Geisberger & Broy, 2012):

1. Merging of physical and virtual world: The challenge is "[…] to merge physical awareness with real-time control of systems and components"[9] (Geisberger & Broy, 2012).

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[8] "[…] den Verbund informatischer, softwaretechnischer Komponenten mit mechanischen und elektronischen Teilen, die über eine Dateninfrastruktur, wie z. B. das Internet, kommunizieren" (Aichele & Doleski, 2014).

[9] "[…] *physikalischen Situationserkennung* (Physical Awareness) und der entsprechenden *Echtzeit*steuerung von Systemen und Komponenten zu verschmelzen." (Geisberger & Broy, 2012)

2. System of systems dynamically changing system boundary: Since CPSs exchange information amongst themselves as well as cooperate with each other, various CPS affiliate to a network. They form a temporary system of systems. As a result of the cooperation of these different systems, functionalities can be expanded.
3. Context-adaptive and autonomously acting systems: Due to the decentralized, semi-autonomous or even fully autonomous control, CPS need to be able to integrate and adapt to the environment and requirements.
4. Cooperative systems with distributed, alternating control: Multiple systems interact in a decentralized manner and autonomous with each other and with the environment.
5. Comprehensive human-system cooperation: Due to the analyzing of data by smart sensors, CPSs are able to interact with their environment, especially with human.

CPS connect the physical world with the virtual world and create numerous and diverse technical opportunities.

CPS and their applications are based on Internet of Things (IoT) enabled infrastructures and protocols (Elsevier, 2016), it is therefore important to clarify the difference between CPS and the IoT. IoT is composed of loosely-coupled decentralized systems of cooperating smart objects, i.e. autonomous physical-digital objects, augmented with sensing/actuating, processing, storing and networking capabilities and can be considered therefore as an enabler for CPS (Elsevier, 2016). Nevertheless, CPS present a higher combination and coordination between physical and computational elements than the IoT (Cimpeanu et al., 2015).

In CPS, the physical and the digital level merge (Broy, 2010). A classic example of Industry 4.0, enabled by CPS is the predictive maintenance. Due to sensors and embedded systems, different parameters of the physical machines are recorded digitally. Based on these data a prediction regarding the future condition of the equipment is calculated on the digital level. The real condition of the system therefore results from the physical object and its digital process parameters (Lasi et al., 2014).

2.1.3.2 Cyber-Physical Production Systems

Cyber-Physical Production Systems (CPPSs) are a similar concept to CPS (Roth, 2016) and play therefore an important role in Industry 4.0 (Pérez, Irisarri, Orive, Marcos, & Estevez, 2015).

CPPSs are applied in the fields of manufacturing and logistics and they are considered as *„[...] enabler for the IoT in manufacturing.“* (Pérez et al., 2015). They support the collection and processing of data in real time by using of sensors and actuators (Pérez et al., 2015; Roth, 2016; Vogel-Heuser & Hess, 2016).

These systems consist of various elements, connected to a network that communicate with each other at different steps of the manufacturing and logistic process (Monostori, 2014). Due to the communication and various actuators and sensors connected to the systems, the CPPS gather and transmit individual data about the production and logistic steps (Roth, 2016). It means that the CPPSs act as autonomous systems in a smart network in the production. Most CPPSs are also equipped with suitable Human-Machine Interfaces (Monostori, 2014; Roth, 2016), and are in these way easy to use.

Due to these opportunities, the so-called “Smart Factory” has been emerging (Zhou, Taigang, & Lifeng, 2015). The elements, such as machines, products and means of production, are becoming intelligent and create smart, flexible as well as better production conditions (Zhou et al., 2015).

2.1.3.3 Internet of Things

The term “Internet of Things” (IoT) was introduced by Kevin Ashton in 1999 (Mattern & Flörkemeier, 2010). Since than it has gained popularity by becoming one of the most important components for enabling Industry 4.0 (Hermann et al., 2016). In IoT the objects are also called smart products or intelligent objects, they are equipped with ubiquitous computing elements and are therefore able to communicate and exchange information with each other (Roth, 2016). These objects can be combined and communicate with each other and the surrounding environment through a smart network, without any kind of human interaction (Brühl, 2015), by creating the basis for complex autonomous systems that play an important role in Industry 4.0.

Because of the ability to connect objects, it is also often called the Internet of Everything (Obermaier, 2016), the Internet of Services or the Internet of Things and Services. This is a concept that represents services offered as a part of innovation and in conjunction with innovative solutions as e.g. smart cars, smart bike rental services etc. (Brühl, 2015; Roth, 2016).

In IoT every object can be clearly and uniquely identified by receiving an unique ID (Roth, 2016). To conduct these steps there are two technologies that are available and often applied. By using the so-called “RFID chip”, the Radio Frequency Identification (RFID) allows automatic and individual identification of objects from a distance of several meters (Mattern & Flörkemeier, 2010; Roth, 2016). A further method for identifying objects is addressing via Internet Protocol (IP). The common used protocol previously was (IPv4) which should be upgraded to the Internet Protocol Version 6 (IPv6) (Kagermann et al., 2013), since the ladder offers a larger number of combinations and makes it possible to provide up to 340 sextillion addresses (Roth, 2016). In this way, the large number of networked objects, which would be required in Industry 4.0, can be covered (Kagermann et al., 2013; Roth, 2016).

When we talk about IoT, it should be clear that it is not u unique innovation or new technology, moreover like the smart phone or other similar products it presents a new combination of existing technologies that offers completely new application possibilities and scenarios (Mattern & Flörkemeier, 2010). In this context Mattern and Flörkemeier (2010) worked out the requirements for the IoT as communication and cooperation, addressability, identification, sensors, embedded information processing, localization and user interface.

In context of Industry 4.0, the Internet of Things and Services becomes increasingly important in the factory and manufacturing processes. By using the Internet of Things and Services technologies as well as concepts, production and processes lead to intelligent networking, such as machines and resources (Kagermann et al., 2013).

Therefore, the objects generate a lot of data, which can optimize processes in the economy and industry (Roth, 2016). This enables the development of entirely new and innovative business models (Kagermann et al., 2013; Mattern & Flörkemeier, 2010).

2.1.3.4 Machine-to-Machine Communication

Machine-to-Machine (M2M) communication is a further important aspect in Industry 4.0 that makes the communication between components possible by setting a basis for automation. It enables also the communication of CPS and CPPS components as important parts of Industry 4.0 (Roth, 2016). M2M communication can be defined as wireless, automated and independent communication and the exchange of information and data transmission between machines (Anton-Haro & Dohler, 2015; Kaufmann, 2015; Roth, 2016). The word machines should be associated with sensors, actuators, and objects (Anton-Haro & Dohler, 2015; Holler et al., 2014).

The M2M technology present a big advancement in Industry 4.0. Through this kind of communication machines become smart and are able to exchange information with one another and the environment (Glanz & Büsgen, 2013).

M2M communication is based on common transmission media such as LAN, WLAN, ISDN and the GSM mobile networks, or a combination of them (Glanz & Büsgen, 2013). Besides the transmission media, it is recommended to use open standards for a platform-independent communication, which enable the exchange of data and information, in context of Industry 4.0 (Roth, 2016).

2.1.3.5 Human-Machine Interaction

Human-Machine Interaction (HMI), often referred to as Human-Computer Integration (HCI), gains value in Industry 4.0. While the M2M plays an important role so that machines can communicate and operate in an autonomous way, it is also necessary for humans to be able to interact with the machines. Therefore HMI is important, e.g. through monitoring and control systems for the production (Roth, 2016).

The interconnected machines, integrated processes and available objects and sensors generate a huge amount of data (Lüder, 2014). It is therefore important to be able to generate an added value from the collected data (Gorecky, Schmitt, Loskyll, & Zühlke, 2014). For this reason, the visualization of the processes and data as an interface for the humans plays an important role (Lüder, 2014; Roth, 2016).

To achieve the visualization, different devices as smartphones and tablets by making use of special interfaces, like Virtual Reality and Augmented Reality can be applied (Lüder, 2014; Roth, 2016). For example, Augmented Reality supports humans in the working environment in factories by assisting with series of information (Gorecky et al., 2014). This information appears in the working field. One example for Augmented Reality is the usage of smart glasses. Virtual Reality provides a replication of life processes (Gorecky et al., 2014).

However the HMI faces some challenges as the large amount of data, the CPS system with automated decisions, interface technologies, conditions in factories as well as the education and training of workers with these technologies (Pfeiffer, Hellmers, Schon, & Thomaschewski, 2016). Due to the big amount of data it is important to filter properly and define which data to show and analyze (Lüder, 2014). Another requirement is *"[…] to establish effortless ways for a CPS to tie into already existing manufacturing information technologies through the use of standardized, platform-independent interfaces."* (Gorecky et al., 2014).

Through the transformation and automation of work processes and the increasing networking of the "World", the stationary workplace disperses. Humans will have the option to access information and data from anywhere and can therefore work from everywhere (Gorecky et al., 2014). In the context of Industry 4.0, the technologies and especially HMI need to evolve in order to meet new emerging requirements.

2.1.3.6 Ubiquitous Computing

The concept of Ubiquitous Computing, is an important concept and system component introduced by Mark Weiser in 1990 (Roth, 2016; Weiser, 1991). Ubiquitous Computing describes the smallest, interconnected as well as intelligent computer needed to process and deliver data to other objects (Roth, 2016). This can be used, for example, in products, production facilities or production machines to support people in their tasks. Ubiquitous Computing offers another component for the Internet of Things and Services by the microelectronics-provided objects (Roth, 2016).

2.1.3.7 Big Data

In Industry 4.0 the objects are connected to each other and generate and analyze a large amount of data also known as Big Data (Kagermann et al., 2013; Miškuf & Zolotová, 2016; Sauer, 2014; Schermann et al., 2014). Therefore, it is significant to understand the concepts and problems behind Big Data (Miškuf & Zolotová, 2016; Wan, Cai, & Zhou, 2015). Dealing with the huge and complex data streaming from e.g. sensors as well as actuators, especially to create a real value from the produced data (e.g. to improve the production process), is one of the fundamental requirements and challenges of Industry 4.0 (Wan et al., 2015).

"Big Data" in this context describes large pools of data that can be captured, communicated, aggregated, stored, and analyzed. Big Data can be defined by the 5Vs (Nambiar & Poess, 2015):

- **Volume** or the large amount of data that either consumes huge storage or entails a large number of records data (Wamba, Akter, Edwards, Chopin, & Gnanzou, 2015).
- **Velocity,** which is the frequency or the speed of data generation and/or frequency of data delivery (Wamba et al., 2015).

- **Variety** to highlight the fact that data is generated from a large variety of sources and formats, and contains multidimensional data fields including structured and unstructured data (Wamba et al., 2015).
- **Value** in order to stress the importance of extracting economic benefits from the available big data (Wamba et al., 2015)
- **Veracity** in order to highlight the importance of quality data and the level of trust in various data sources (Wamba et al., 2015). If data is not of sufficient quality by the time it has been integrated with other data and information, a false correlation could result in the organization making an incorrect analysis of a business opportunity.

2.1.3.8 Security

One of the biggest challenges that come with Industry 4.0 is security (i4.0, 2015). The objects get smart through sensors and actuators as well as further technologies. In this way, they become also autonomous. Furthermore, the objects are all smart and connected to one another through the internet. These creates potential for malicious attacks that can have undesired and risky outcomes. Therefore, the security issue becomes a very important topic in Industry 4.0 (Drath & Horch, 2014; Kagermann et al., 2013).

IT-Security: IT security is considered as a concept where three components as confidentiality, integrity and availability of IT systems are achieved. Due to the connection of the machines in Industry 4.0 through the internet, they can be objects of cyber-attacks. This is e.g. very important for CPS and CPPS systems that can be attacked to cause harm. Therefore concepts of security that include security blueprints, security-by-design, secure engineering, secure infrastructures, should be introduced (Waidner & Kasper, 2016). Beside this, introduction in methods of authentication and cryptographic e.g. hash algorithms or symmetric/asymmetric primitives should be presented (Waidner & Kasper, 2016).

Data Security: In data security the confidentiality and integrity are an essential part (Kagermann et al., 2013). Through the interconnection, more data is generated. Therefore methods to protect from attacks on data such as cryptographic and encryption algorithms should be introduced (Sadeghi, Wachsmann, & Waidner, 2015). In this context identification management of machines, product and users regarding authentication and authorization procedures, end-to-end security, industrial rights management for controlling access to data and services are a further essential topic (Drath & Horch, 2014; Kagermann et al., 2013; Waidner & Kasper, 2016).

2.1.4 Relevance for Education and Qualification

Jeschke et al. (2015) recommend concrete measures for teaching Industry 4.0 as they consider Industry 4.0 teaching as a key challenge for further development. In their work, they introduce the German term *Ausbildung 4.0 – Teaching 4.0*. They suggest that it is necessary to adapt the content of teaching and training in the areas of IT in order to be prepared for the challenges that Industry 4.0 will present.

Another study about the challenges for teaching and training in the area of Industry 4.0 suggest that:

- An economical and technical education will offer good employment chances in the context in Industry 4.0;
- To have a job certainty it is important to be able to use and understand decentralized and intelligent system, as well as bring knowledge of data collection and analysis;
- The number of jobs for unqualified people will drop;
- There are for the moment no new jobs that arise through Industry 4.0, however the existing one are changing and the employees should learn new competencies;
- The teaching and training offering about I4,0, CPS, data analytics and IT security should arise. (vbm', 2016)

2.1.5 Industry 4.0 in the Context of this Thesis

“It should be noted that the term Industry 4.0 is widespread in German speaking countries. However, similar concepts and visions are often used under another term in the international context. For instance, Industry 4.0 is known by the term „industrie du futur“ in France, or the „Industrial Internet“ (Grangel-González et al., 2016) as well as further similar concepts as „Internet of Things“, „Internet of Everything“ „Smart Factory“ or “Digital Transformation” in the international context (Obermaier, 2016; Roth, 2016). All this concepts include the use of automation, real-time, sensors and further modern technologies to transform business processes and therefore achieve a business value, however they slightly differ from one another in various aspects. For the purpose of this study we refer to Industry 4.0 as a German concept with regards to the definition presented above that considers Industry 4.0 as:

[...] the fourth industrial revolution, its aim is a more efficient, flexible and individual production achieved through decentralized controls of production and completely digitally controlled or even self-organized value chains and where automation, real-time and sensor technologies play a crucial role.” (Prifti, Knigge, Kienegger, et al., 2017)

2.2 Curriculum

2.2.1 Structure-Oriented vs Process-Oriented Curricula

While considering the curriculum definitions there are two main approaches or viewpoints mainly considered in literature and practice: The structure-oriented and the process-oriented approach (Fraser & Bosanquet, 2006) as presented in Figure 4. Salden, Fischer, and Barnat (2016) also mention a third approach, the didactic-approach. This approach creates a link between the content and the methods applied in a curriculum. However, this approach is not widely applied and is very similar to the process-oriented approach, therefore in this section the focus will lie on the two most applied approaches. The structure-oriented approach is lecturer centered while the process-oriented approach is student centered as presented in Table 1.

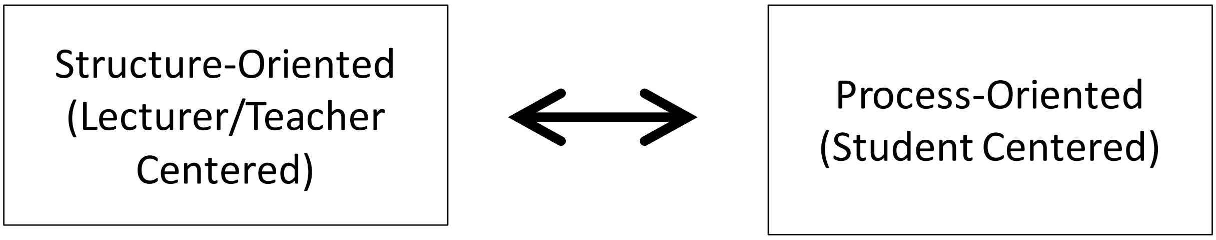

Figure 4: Curriculum Classification based on Fraser and Bosanquet (2006)
(Source: Own Representation Based on Lahiff (2009))

2.2.1.1 The Structure-Oriented Approach

The structure-oriented approach considers a curriculum as a product and defines the structural requirements for a course. These requirements offer therefore a standard for all courses. In Europe e.g. these requirements are determined by KMK (2010) and Akkreditierungsrat (2013) in intervals of several years, and define e.g. that all bachelor courses contain a scope of 180 credit points and are based on specific modules (Salden et al., 2016).

Table 1: Teacher vs Student Centered Approaches
(Source: Own Representation Based on Harden, Sowden, and Dunn (1984))

Teacher Centered Approach	Student Centered Approach The Student Decides (under the Guidance of the Teacher):
The Teacher Decides: • Learning Objectives • Course Content • The Method the Student will use to Achieve the Objectives • The Learning Resources • The Sequence and Pace of Learning • Time of Assessment	The Student Decides under the Guidance of the Teacher: • Learning Objectives • Course Content • The Method the Student will use to Achieve the Objectives • The Learning Resources • The Sequence and Pace of Learning • Time of Assessment

In this context the learning outcomes and the learn activities are considered as products. These curricula are developed based on a general framework and standards and on the knowledge of the experts of the discipline (Barnett & Coate, 2005).

The students learn from a curriculum that is based on the learning outcomes. At the end, the success of the curriculum is measured based on the level how the learning outcomes were achieved. The content is specified by the teacher or lecturer, who defines what need to be taught and learned. Therefore, this approach is also defined as teacher centered approach. The students learn based on the structure given by the lecturer or teacher. Therefore these curricula are considered as products and are called teacher focused curricula (Fraser & Bosanquet, 2006).

Gosling and Moon (2001) mention that curricula based on learning outcomes are finding a growing application in universities, e.g. the Bologna process with ETCS points applies these kind of curricula and evaluation concepts, where the learning outcomes are measured at the end. To use the curricula as products Gosling and Moon (2001) suggest the following principles:

1. The learning of any kind can be expressed in measurable results.
2. Learning modules are described based on the learning outcomes.
3. These two factors give the specific number of ECTS points that are applied. The way how the content is mediated does not play a role.
4. Learning outcomes need to be formulated in a specific and clear way.
5. Learning outcomes identify the learning effort in order to reach the mentioned points.
6. The evaluation criteria should measure the extend in which the learning outcomes were reached.
7. The evaluation criteria should be motivating for learning more.
8. The product view of the curricula should make it possible to compare the curricula between different institutions. (Gosling & Moon, 2001)

2.2.1.2 The Process-Oriented Approach

The other view defines curricula as processes through the continual activity and interaction between students, lecturers, knowledge and environment (Cornbleth, 1990). In this way it is possible to reflect changes in the society and disciplines in a fast way (Fraser & Bosanquet, 2006). The process-oriented approach includes the coordination of the stakeholders within the entire process, where the curriculum development passes through an ongoing process (Salden et al., 2016).

As a difference to the curricula defined as products, in this case the students are the generators of the knowledge. The curriculum arises as a systematical reflection through action and the curriculum is developed during the learning process (Barnett & Coate, 2005). The curriculum development is a dynamic process and does not follow a predefined framework (Fraser & Bosanquet, 2006).

Hubball and Burt (2004) suggest how the process driven curricula could be developed and what the important points with regards to them are. Curricula should:

- Be developed together with the students and the faculty,
- The learning content is developed in different phases and should be continually further developed,
- Include different strategies of learning and teaching,
- Be an individual and social process at the same time. (Hubball & Burt, 2004).

The process oriented curricula bring the following advantages:

- They inform the students about what they should learn and the students are able to define their learning program and invested time by themselves,
- They show the learning outcomes, similar as the product oriented curricula, in this way time and content can be planned,

- They include the students in the development of the learning objectives, the learning content, learning activities as well as the evaluation (Hubball & Burt, 2004).

2.2.2 Models of Curriculum Development

After describing the main two approaches in materializing a curriculum above, I will address some models for curriculum development:

Process oriented approaches: There are several process oriented approaches. Here however three approaches as described by Salden et al. (2016) that are similar to one another will be described. Flechsig (1973) describes a curriculum as a plan by considering five steps. In the first step, also called the information phase, a course of study is planned. This is followed by the decision phase, where the course is designed from a proper department in the university. The final three steps are design, development and evaluation phase, which attain the goal of a detailed review.

Wilbers and Wittmann (2013) consider the stakeholders of the curriculum as the most important actors that need to come to an agreement in the process of a curriculum development. They mentioned stakeholders as students, instructors, deans, administration staff etc.

The process according to Jenert (2012) defines a model of two following levels:

1. Program Leadership: Stakeholders are involved in the process. They define the targeted goals of the curriculum.
2. Program Ownership: Contains elements, which transfer the content to students to gain the learning outcomes.

These three described approaches from Flechsig (1973), Wilbers and Wittmann (2013) and Jenert (2012) for curriculum development have a similarity. They all rely on the curriculum stakeholders and put them as important actors in the curriculum development process.

Competency-based curriculum development: Schaper et al. (2012) present a competency-based curriculum development by distinguishing between content-conceptual and organization-developing aspects. While the organization-developing steps are of an organizational and bureaucratic nature in a university and not on the focus of the thesis, the content-conceptual aspects includes the phases (Schaper et al. 2012):

1. Phase: Determination of qualification objectives or competencies
2. Phase: Define learning outcomes for the curriculum based on taxonomical criteria and systematics
3. Phase: Development of guidelines for teaching, learning and examination methods
4. Phase: Develop learning unit content including theoretical and practical part
5. Phase: Develop accompanying measures for the implementation of the curriculum e.g. mixing teaching methods, describe how a lecturer could conduct his lecture
6. Phase: Develop evaluation mechanisms for each of the learning units in order to measure if the intended learning outcomes and competencies were achieved

The approach suggested by Schaper et al. (2012), follows mainly a structure-oriented approach, although it is also combined with elements of the process-oriented approach. Schaper et al. (2012) put their focus on the competencies by suggesting a competency-based curriculum development. They suggest in teaching the necessary competencies to students, in order for them to be able and best fitted for a job.

Therefore, the goal of the competency-based curriculum is not only the acquisition of domain knowledge in a certain discipline or area of expertise, but also in learning additional competencies by applying the learned knowledge in the professional and interdisciplinary fields (Schaper et al. 2012).

Schaper et al. (2012) recommend therefore in starting the development process with the definition of the competencies. Afterwards they suggest in defining learning outcomes and the teaching and learning methods. As a consequence of this competency oriented approach, it is possible to design an effective and purposeful learning. A further advantage of the competency-based curriculum is the clear and transparent demonstration of the learning outcomes as well as designing of learning and teaching. This leads regarding to Schaper et al. (2012) to an effective learning and satisfaction of students. The final evaluation and revision of the curriculum is appropriate to identify gaps and to optimize the developed curriculum. This approach in curriculum development offers therefore many advantages, therefore this approach was also chosen for the development of the competency-based curriculum in the context on this thesis.

Nevertheless, a competency-based curriculum also accommodates several challenges. By being oriented to a certain field of qualification, and aiming in teaching those competencies it may lead to a one sided focus of the students. A competency-based curriculum offers also a complicated construct of content as well as learning methods, accompanying measures and evaluating tools. It means that it is difficult in addressing changes that may occur in the requirements for education. In order to avoid these risks it is therefore recommended to pay attention to them during the definition of learning objectives and at the designing of the modules, so that changes can be easily adapted.

The Constructive Alignment: The constructive alignment is a popular method in curriculum development (Biggs, 2003) and it is an outcomes-based approach of teaching. This approach is based on the concept of constructivism and consists of four development steps for the curriculum. The first step is defining the learning outcomes. Biggs (2003) distinguishes between declarative, already known knowledge, and functioning knowledge, which imply the transformation of declarative knowledge into functioning knowledge. The functioning knowledge describes the ability of the students to apply the acquired skills in practice. Further it is suggested to define the level of fulfilment for each learning outcome, e.g. it is recommended to use verbs such as "define" or "explain" (Biggs, 2014) for defining them. For this, Biggs and Tang (2007) recommended the SOLO taxonomy, which defines verbs for each level. In the second step of this curriculum development approach, the teaching and learning activities are defined. The third and fourth steps consist in the assessment of the students learning outcomes and their grading. This is also due to the outcome based character of this approach. By focusing on the outcome it is important to put special effort in measuring the level of the fulfillment for the predefined outcomes. Biggs and Tang (2007) describe two kind of assessment methods that can be applied, the formative assessment and the summative assessment. Formative assessment gives students feedback during learning, while summative assessment includes the grading at the end of the module (Biggs & Tang, 2007).

The described constructive alignment as suggested by Biggs (2003) is an outcome-based model, very popular in the curriculum approaches. It focuses on the learning outcomes similar to other approaches proposed by e.g. Kerr and Berman (1968); Nicholls and Nicholls (1978). However it defines also the verbs for formulating these learning outcomes and different levels for mastering each outcome, based on the used verb. This is with regards to Biggs (2014) an important aspect. By defining the objectives and goals of a module with verbs, students understand and realize *"[...] the relevant learning activities"* (Biggs, 2014), which supports to achieve the identified learning outcomes. Furthermore, Biggs (2003) considers the assessment as an important step of the learning process by suggesting two forms of assessment the formative and summative ones. In this way it help students and also teachers gain feedback about the learning process and measure how the learning objectives are mastered (Biggs, 2003). The purpose of this approach is to enable a transparent model, where students understand the learning objectives regarding the learning activity how to learn and how grading these goals.

Four Steps Approach: Offorma (2014) describes and summarizes a number of curriculum development approaches. One of them is the Four Steps Approach, described by researchers as Giles, McCutchen, and Zechiel (1942), Tyler (1975) as well as Kerr and Berman (1968). Each of these researchers describe a curriculum developing process, consisting of four steps and have similarities with one another. According to Giles et al. (1942), the first step in developing a curriculum is in defining the objectives so that all the following steps are based on the curriculum objectives (Offorma, 2014). Therefore the four steps are: Selection of objectives, Selection of learning experience, Organization of learning experiences as well as Evaluation.

Tyler (1975)'s model is well-known in the education literature and similar to the work of Giles et al. (1942) aims in defining the curriculum goal at the beginning of the process by asking the questions: "What educational purposes should we seek to attain? What educational experiences can be provided that are likely to attain these purposes? How can these education experiences be effectively organized? How can we determine whether these purposes are being attained? (Offorma, 2014; Prideaux, 2003; De Villiers, 2001). These (behavioral) objectives *"[...] should be written in terms of changed behavior among learners that can be easily measured."* (Prideaux, 2003).

Kerr and Berman (1968) provide a four steps curriculum development process too. In comparison with the other four steps approaches, Kerr and Berman (1968) does not recognize the organization of learning or education experiences. Besides the similar steps he identifies "Selection of content" as second step.

Offorma (2014) analyses these three models by mentioning the similarities between them. Giles et al. (1942),Tyler (1975) and Kerr and Berman (1968) suggest each a four steps approach. Giles et al. (1942) and Tyler (1975) approaches are nearly similar only with the difference that Giles et al. (1942) defines four components, which influence each other. As a consequence of this model the components are interdependent (Hunkins & Ornstein, 1988; Offorma, 2014).

Tyler (1975) identifies the steps as a liner model, where *"[...] one step leads to another [...]"* (Offorma, 2014). According to Offorma (2014) this approach could lead to a good curriculum, which provides the advantages to be always on track by following the steps and objectives. However, *„ [...] the model restricts the curriculum to a narrow range of student skills and knowledge [...]"* (Prideaux, 2003).

The model suggested by Kerr and Berman (1968) does not provide an organization of the learning experiences in comparison to Giles et al. (1942) and Tyler (1975), which can be considered as significant drawback of the model (Offorma, 2014).

Five Steps Approach: In the next step Offorma (2014) summarizes and describes the five steps approaches recommended by Nicholls and Nicholls (1978) and Wheeler (1978). Nicholls and Nicholls (1978) recommend following five steps for the curriculum development. Additionally to the four steps approaches described above, they suggest to conduct a situational analysis at the beginning. This situational analysis contains *„[...] the diagnosis of all the factors and issues involved in curriculum planning and development."* (Offorma, 2014). Through the situation analysis it is possible to clearly set the goals for the curriculum and plan all the steps for achieving the objectives and it also helps in better defining the objectives (Mulenga, 2014; Offorma, 2014). Also compared to the four steps approaches from Giles et al. (1942) and Tyler (1975), which propose the selection of learning or education experiences, Nicholls and Nicholls (1978) also suggest as a third step the selection of the content. In the fourth step it is suggested to define the methods which are equivalent to the organization of learning or education experiences. The scope of both is the organizing and preparation of teaching materials for the students. The fifth step is the evaluation as also in the four steps approach (Nicholls & Nicholls, 1978). The whole approach is cyclic and many refinement cycles can be conducted until achieving the desired results for the curriculum.

Wheeler (1978) describes also a cyclic five steps process for curriculum development. Wheeler's model separates, compared to the other models, between „Selection of content", „Selection of learning experiences" and also „Organization of content and learning experiences". According to Offorma (2014) the content contains all aspects about the subject, which will be taught to the students, such as facts and ideas. The characteristic of a cyclic model, which permits to start from any point, represents "[...] a continuous and on-going process" (Offorma, 2014). Therefore, cyclical models are flexible and adaptable to situations and issues changes (Mulenga, 2014). Moreover, cyclic approaches have the advantages through the "logical sequential structure" to guide to a powerful curriculum (Mulenga, 2014). Besides the advantages, there is also a disadvantage to this curriculum development models. Both, the linear and even the cyclic model do not determine the design and implementation details (De Villiers, 2001).

Seven Steps Approach In the category of seven steps approaches Offorma (2014) describes the model of Taba (1962). Taba (1962) provides a curriculum model containing seven steps that include: situational analysis, selection of objectives, selection of learning experiences, organization of content as well as evaluation (Offorma, 2014).

Taba (1962)'s model include the situation analysis similar to the model proposed by Nicholls and Nicholls (1978). However Taba (1962) also defines further factors for the situational analysis as *„[...] the learner, the teacher, the learning process, the nature of available accumulated body of knowledge, the nature of the educational system and facilities, the nature of the society, and environmental influences on the learner."*. Similar to the model of Wheeler (1978), Taba (1962) also distinguishes between learning experiences, content and organization. He also defines curriculum objectives similar to the models of Tyler (1975) and Taba (1962).

Six Steps Approach: Offorma (2014) describes a further curriculum development model, established at the John Hopkins University by Kern, Thomas, Howard, and Bass (1998). This six steps approach is intended for medical education. The six steps were classified and defined as follows (Kern et al., 1998):

1. Problem identification and general needs assessment: In this part of the curriculum development the „identification and critical analysis" of the topics to be taught and the needs assessment are derived (Offorma, 2014).
2. Needs assessment of targeted learners: This step is a new view of curriculum compared to the others. Here the learners are in focus (Kern et al., 1998; Offorma, 2014).
3. Goals and objectives: Kern et al. (1998) suggest defining „broad or general goals" at first. These are followed by „specific" and „measureable objectives", which can encompasses cognitive knowledge, affective attitudinal and psychomotor skill or performance.
4. Educational strategies: Satisfying the determined goals and objectives. The content and also the educational methods are selected in this step. Kern et al. (1998) recommend active teaching and learning methods such as case-based and problem-solving exercises.
5. Implementation: After the setting of objectives and methods, the implementation plays a significant part. This includes according to Kern et al. (1998) political support, resource identification, determined barriers for implementation, introduction as well as administration to the curriculum.
6. Evaluation and feedback: The last step includes the evaluation of the curriculum similar to other model approaches. The feedback can be used to improve and elaborate the current curriculum. Moreover, evaluation and feedback can also be used to measure the effectiveness of the curriculum.

„Know, See, Plan, Do" (KSPD): The KSPD curriculum model was introduced by Allen, Miguel, and Martin (2014) for the development of curricula in the leadership development. The KSPD model is broken down to four steps. These steps are defined as: "

1. **Know:** Obtaining declarative knowledge of terms, concepts, facts, and theories.
2. **See:** Identifying and recognizing the concepts in others or the environment.
3. **Plan:** Integrating existing knowledge to develop a plan of action.
4. **Do:** Intervening skillfully when carrying out the plan of action." (Allen et al., 2014)

The described approach analyses the curriculum development from another perspective. Allen et al. (2014) suggest at first that students (in this case for leadership development) acquire declarative knowledge. This knowledge is transformed in procedural knowledge in the second step, where the students are required to apply critical thinking and apply the declarative knowledge. This leads to the advantages that the curriculum encourages the process from *"[...] novice to expert."* (Allen et al., 2014). By the active participation of students, they get the chance to improve their observing and analytical capabilities (Allen et al., 2014). From step See to step Plan, students should gather problem-solving skills. Allen et al. (2014) recommend for instance consulting conversations or videos, where students must identify the problem solutions. The last step is the Do step. This step should contain activities, which "[…] allow students to move through all four components […] and culminate with an opportunity to implement an actual plan" (Allen et al., 2014). However this is a very specific curriculum development approach that can be applied for leadership or similar educational goals.

Three Steps Approach: Halaman (2016) presents a model for a curriculum development, consisting of three steps that is based on Grayson (1978). It encompasses three basic steps as: Problem definition, Structuring the curriculum as well as Implementation and evaluation. During the problem definition it is important to include a mission statement. This steps takes the industry, societal and professional needs into account, which is close to the approaches of Nicholls and Nicholls (1978) and Taba (1962), who defines it as Situational analysis and Offorma (2014), who also defines it as needs analysis. The second step is divided in sub-steps as domain of knowledge, student constraints, accrediting body, resources and teaching and learning methods. Halaman (2016) suggests in this step two further phases. These phases should organize the elements in the curriculum and consider ensuring detailed structuring of determined courses (Halaman, 2016). Similar to other models, the last step requires the evaluation of the curriculum where the measuring of the output in exams and performance during the courses of students are suggested.

According to Halaman (2016) the process is *"[...] highly iterative with multiple secondary interactions and revisions before moving on to the next stages."*.

SPICES: SPICES is a specific model, applied mainly in the medical education. This model is however analyzed since it has a strong focus on student centered curriculum approaches. It shifts the focus from teacher-centered learning to student-centered learning, from information gathering to problem-based learning, from discipline-based teaching to integrated teaching, from hospital-based education to community-based education, from standard program to electives and from apprenticeship or opportunistic program to systematic (Harden et al., 1984). According to Harden et al. (1984) changing to a students' centered approach transforms the point of view and puts the students in the focus of content delivery and knowledge generation. They also suggest an integrated teaching instead of the traditional discipline-based teaching. Integrated teaching means a horizontal or vertical integration of all subjects in the curriculum, which should be connect to present "[…] to the students as a meaningful whole" (Harden et al., 1984). Horizontal integration combines parallel curricula that are conducted in the same year. While the vertical integration integrate curricula in different phases (Harden et al., 1984). The community-based education gives the medicine students the possibility to get to know the work environment and gain practical experience. Harden et al. (1984) also suggests that the study program should be elective by giving students the possibility to put together their own study program. Systematic is a program, which "[…] is designed for all students so that the experiences necessary for their training are covered" (Harden et al., 1984). By the systematic approach the skills are clearly defined and in regards to medical students they obtain transparent clinical experiences (Harden et al., 1984).

The SPICES model transforms the classical way of teaching, which means it is a high effort for teachers and lecturers to adapt to this kind of teaching (Harden et al., 1984). The suggested problem-based learning increases problem-solving skills, body of knowledge, students' motivation and retention (Harden et al., 1984). However some basic concepts and understandings cannot be learned in a problem based environment. The community-based education affords an understanding of community function and their role in the community. They are able to improve their learning experiences and it also enhances an active learning. This approach should be followed also in further disciplines other than medicine and would help in promoting further skills. It is also suggested that students are able to the courses themselves from a broad range of elective courses. This is a positive approach that would help students in following their own interest and focusing on the topics they want to. However this approach is very time consuming and difficult to organize for the lecturers (Harden et al., 1984).

Integrative Approach: Khan and Law (2015) propose the integrative approach composed of five steps. The approach reminds to keep in mind the factors of society, industry, government while developing the curriculum, in order to develop coherent content that is relevant for the practice. The model starts with an analysis of the current situation similar to the situation analysis. They called it as internal and external environmental scanning. In the second step, based on the example of the environment analysis, the graduate competencies are defined. Graduate competencies contain the specified competencies, which are grouped by personal, professional and institutional. In the third step the curriculum is developed. The fourth step comprises the determined pedagogical strategies. And finally, as with most approaches this process also obtain implementation, evaluation and feedbacks.

The integrative approach by Khan and Law (2015) conducts a situational analysis, similar to the approaches of Nicholls and Nicholls (1978), Taba (1962) and Kern et al. (1998). This approach has to challenge with difference learning styles and teaching styles, the time-consuming process to involve institutional stakeholders, which occurs by different opinion and objectives and limited resources (Khan & Law, 2015).

Discursive Curriculum Development: This model is suggested by Gerholz and Sloane (2016). It combines the technocratic and social curriculum model and the organizational theory perspective. At first Gerholz and Sloane (2016) introduces a technocratic curriculum model, which is based on the structure-oriented approach. The model follows certain specification by creating a linear process. By following these steps the modules, module goals as well as content are defined. The implementation and evaluation are not part of this model. The discursive curriculum development approach arise as described below:

1. Model of course: Contain the objectives of the course of study and implies socio-cultural factors).
2. Curriculum conception: Construction of the module with three possible aspects (science, situation principles and principles of personality).
3. Module development: Structure and design of the modules based on curriculum conception.
4. Sequencing of modules: Modules should be structured in a form that students get the opportunity to build skills sequentially.
5. Evaluation and revision

In the suggested model the teachers are responsible for the design of the modules. It is important to specify the modules aspects such as the aim and content as well as implying didactic skills.

Compared to other approaches of curriculum development the discursive curriculum model is rather complex (Gerholz & Sloane, 2016). The discursive model also respects the question of higher education didactics and as a result of this, Gerholz and Sloane (2016) assign the model to a didactic modeling of course of higher education.

Each of the described models has a different focus and advantage. Based on the goal why a curriculum is being developed and in which context it is going to be used, a suitable model can be chosen. For the purpose of this thesis the six-step approach for the development of a competency-based curriculum will be applied, since the goal is in teaching the defined competencies.

2.2.3 Curriculum Concept in the Context of this Thesis

The concept of curriculum is one of the main concepts used in teaching and learning and is used mostly with two different meanings. While some authors define a curriculum as a whole study program including various courses to achieve an academic degree, others use this term for a specific course and its contents. Offorma (2002) defines a curriculum as a "*document, plan or blue print for instructional guide, which is used for teaching and learning to bring about positive and desirable learner behavior change. Curriculum content is made up of the subject matter to be taught, body of knowledge, topics, ideas, concepts, symbols, facts and cognitions, presented to the learners*". For the purpose of this thesis, based on the curriculum concepts and models described above, a curriculum is defined as:

"a collection of documents and learning activities aiming in delivering a structured series of learning experiences that includes theoretical and practical content to deliver predefined competencies to the learner".

2.3 Competency

2.3.1 Competency Definitions

The concept of competency has been subject of research in various disciplines as psychology, education, organizational management, human resources or information systems. There is much debate about the concept and no clear definition or common understanding (Delamare Le Deist & Winterton, 2005). E.g. a competency is already defined very early as "a personal trait or set of habits that leads to more effective or superior job performance" (McClelland, 1973). Further authors define it as a characteristic or an ability as e.g. "an underlying characteristic of a person, which results in effective and/or superior performance on the job" (Klemp, 1980); "underlying characteristic of an individual that is casually (change in one variable cause change in another) related to superior performance in a job" (Boyatzis, 1982); "the ability to perform effectively the functions associated with management in a work situation" (Hornby & Thomas, 1989); "an observable skill or ability to complete a managerial task successfully" (Jacobs, 1989); "the characteristics of a manager that lead to the demonstration of skills and abilities, which result in effective performance within an occupational area. Competency also embodies the capacity of transfer skills and abilities from one area to another." (Hogg, 1989).

In later years a competency is strongly connected with the concept of skill as by the following authors e.g. "skills & abilities-things you can do -acquired through work experience, life experience, study or training" (Spencer & Spencer, 1993); "the skills, abilities, and personal characteristics required by an „effective" or „good" manager" (Page & Wilson, 1994): "as the state of being competent refers to having the ability to consistently produce the results (the worthy outcomes of behavior) that are required for the most efficient and effective achievement of the larger organizational goals" (Gilbert, 1996).

Further on this concepts becomes broader by being described as a combination of skills, knowledge and ability as by the further authors: "those characteristics- knowledge, skills, mindsets, thought patterns, and the like-that, when used either singularly or in various combinations, result in successful performance" (Dubois, 1998); "an underlying characteristic of a manager which causally relates to his/her superior performance in the job" (Evarts, 1988); "the skills, knowledge and understanding, qualities and attributes, sets of values, beliefs and attitudes which lead to effective managerial performance in a given context, situation or role" (Woodall & Winstanley, 1998).

In the latest years this concept took a whole new dimension by being defined as a "sets of behaviors that are instrumental in the delivery of desired results or outcomes" (Bartram et al., 2002). (Chouhan & Srivastava, 2014)

These are only some examples of the various directions and definitions used with regards to competencies that show how this concept has been used and evolved over time, from the description as a simple characteristic to a set of behaviors.

2.3.2 Competency Dimensions

Apart from the mentioned definitions and nuance above, the concept of competency is also broadly research and handled in different dimensions in the literature:

Competency vs Capability: While many competency definitions were provided above, a capability is defined as "[…] a feature, faculty or process that can be developed or improved. Capability is a collaborative process that can be deployed and through which individual competencies can be applied and exploited." (Vincent, 2008)

Vincent (2008) demands a more precise differentiation between the terms "Competency" and "Capability". However there is no clear difference in the literature. Stalk, Evans, and Shulman (1991) also tried in making a differentiation between the two terms, however they did not succeed in providing clearly defined descriptions (Javidan, 1998). In the context of computer education, Phelps, Hase, and Ellis (2005) state an ongoing competency/capability debate and demand clearer definitions. Nevertheless, this term are often used as synonyms in many contexts of the literature.

Competency vs Qualification: The following definition about qualification could be found in the literature *"Qualifications ... describes the ability ... meaning knowledge, qualifications, capabilities that persons possess and that are used in practicing a professional activity"*[10] (Teichler & Schomburg, 2013).

So the term qualification is a specialized term used more in the case of education and training. The qualification defines the requirement for education and it should be accompanied by issuing a certificate (Heinen, Frenz, Djaloeis, & Schlick, 2010).

Competency vs Performance: The terms competency and performance are often used as synonyms (Basellier, Reich, & Benbasat, 2001). However there is a difference between two terms as competency is the enabler, providing the means to a better performance (Klemp, 1979). This terms are related, but performance may have many others influence factors that just competency. So apart from the competency also other factors as the environment, motivation, support etc. are necessary to achieve performance (Schambach, 1994). A competent employee may not be performant.

Competency vs Skill: Many competency studies are discipline related and try in defining the competency or specific skills for a particular job (Willis, 1990). Marcolin, Compeau, Munro, and Huff (2000) define a competency *"as the user's potential to apply technology to its fullest possible extent so as to maximize the user's performance on specific job tasks"*. This is a clear

[10] *Als Qualifikationen [...] werden Befähigungen (oder auch nur die erlernten Befähigungen), d.h. Kenntnisse, Fähigkeiten und Fertigkeiten, über die Personen verfügen, bezeichnet, die bei der Ausübung einer beruflichen Tätigkeit [...] zur Verwendung kommen können."*

skill based view to the competency concept. The skill based approach assigns a predefined task and defines the skills that a person should bring to fulfil this task (Basellier et al., 2001).

There is however a difference between skill and competency. A skill is predefined and job specific. There is a limitless amount of skills worldwide. A competency on the other side is more generic and applies across jobs and domains. There is a limited number of available competencies, since the competencies define the ability to learn the needed skills for a job (Bartram, 2012).

Competency vs Personally Trait: There is a further perspective on the term of competency that considers it a personal trait by including characteristics related to the individual (Willis, 1990). Haynes (1979) defines competency as *"generic knowledge, motive, trait, social role, or skill of a person linked to superior performance on the job"*. In this context the competencies represent *"the range of self-perceptions that exist about an individual manager's performance, encompassing also the irrationality and unpredictability of personal feelings"* (Brown, 1994). This includes also aspects of emotional intelligence as well as intellectual abilities, motives and personal traits (Kanungo & Misra 1992). This view allows also in including behavioral aspects in the dimension of competencies (Woodruffc, 1991). E.g. Bartram et al. (2002) state that competencies are *"sets of behaviors that are instrumental in the delivery of desired results or outcomes"*.

Competency vs Knowledge: The concept of knowledge is also closely related to competency and often interchangeably used. In this concept a combination of explicit and tacit knowledge complete an individual and give him the ability to perform well (Basellier et al., 2001).

Similar to the concept of skills however there is a difference between competency and knowledge. While knowledge describes the know-how about a specific topic or a specific job, and the variations of knowledge that can be adapted is limitless in the world, a competency describes the ability to adapt this knowledge while required on the job and apply it accordingly for achieving the needed results (Bartram, 2012). There is however a strong correlation between the two topics and knowledge is a part of the competency concept.

2.3.3 Research Approaches

Research on competencies has been very broad and have developed in different directions (Delamare Le Deist & Winterton, 2005). One of the factors influencing it is also the cultural aspect (Cseh, 2003). In different cultures and countries the research on competencies has taken a different direction. Therefore the three main approaches that are present in the literature and were developed independently are addressed below (Delamare Le Deist & Winterton, 2005).

The Behavioral Approach: The behavioral approach can be considered as the US tradition and has found its main development between US researchers (Delamare Le Deist & Winterton, 2005). This concept was at first introduced by White (1959) that connected the concept of competency with characteristics regarding the personality that lead to a better performance in the job. The term competency was first introduced by McClelland (1973), as he described this as the ability to deliver a superior performance. The behavioral approach, focuses on attributes which go beyond the cognitive ability as self-awareness, self-regulation and social skills (Boyatzis, 1982; McClelland, 1973). This approach argues that competencies are fundamentally behavioral unlike personality or intelligence and can be taught through learning and development (McClelland, 1973). As Spencer and Spencer (1993) defined it, a competency includes: *"motives, traits, self-concepts, attitudes or values, content knowledge, or cognitive or behavioral skills – any individual characteristic that can be measured or counted reliably and that can be shown to differentiate significantly between superior and average performers, or between effective and ineffective performers."*

This tendency has been maintained in the US and supported also by different government initiatives that define core competencies and take measures to push these in education (Delamare Le Deist & Winterton, 2005). These competencies has gain also an important role in the Human Resource Management (Delamare Le Deist & Winterton, 2005) where they are applied in the development as well as in the selection of the employees (Allbredge & Nilan, 2000; Athey & Orth, 1999; Dubois, 1998; Foxan, 1998; Naquin & Holton, 2002; Rodriguez, Patel, Bright, Gregory, & Gowing, 2002). In this usage however competency has a broader focus by including also skills, knowledge and behavioral characteristics (Delamare Le Deist & Winterton, 2005).

In the US literature e.g. Aragon and Johnson (2002) or Boon and van der Klink (2002), also job related, functional competencies are introduced to the concept by connecting them with associated underpinning behavioral competencies (Delamare Le Deist & Winterton, 2005). The todays concept on competencies is based on the behavioral approach as introduced by McClelland (1973), follows a broader definition, by combining the behavioral competencies with job-related functional skills and underpinning knowledge (Delamare Le Deist & Winterton, 2005)

The Functional Approach: The functional approach was developed in the UK in the 80s. It was an initiative of the government due to recognized deficits in skill formation in UK. The UK government introduced the competency-based approach in order to establish a nation-wide system for work qualification (Delamare Le Deist & Winterton, 2005).

The functional approach focuses on competencies as requirements for successfully fulfilling a task by restricting the term of competencies to the skills and know-how required for conducting the task (Frank, 1991; Miller, 1991). It consists on the possessing the functional abilities for a job. See e.g. *'the ability to perform activities in the jobs within an occupation, to the standards expected in employment'* (Beaumont, 1996). This concept of competency was also adapted by the government as *'The ability to apply knowledge, understanding and skills in performing to the standards required in employment. This includes solving problems and meeting changing demand.'* (Beaumont, 1996)

While the functional competency approach in the UK was the center of the research and also applied from the government, there were also some further developments that introduced behavioral elements to this approach (Delamare Le Deist & Winterton, 2005). Hodkinson and Issitt (1995) suggests in including more elements to the approach and Cheetham and Chivers

(1996) and Cheetham and Chivers (1998) suggested five sets of interconnected competencies by suggesting a competency framework. This framework has five dimensions:

- "Cognitive competency, including underpinning theory and concepts, as well as informal tacit knowledge gained experientially. Knowledge (know-that), underpinned by understanding (know-why), is distinguished from competency.
- Functional competencies (skills or know-how), those things that 'a person who works in a given occupational area should be able to do. . .[and] able to demonstrate'.
- Personal competency (behavioral competencies, 'know how to behave'), defined as a 'relatively enduring characteristic of a person causally related to effective or superior performance in a job'.
- Ethical competencies, defined as 'the possession of appropriate personal and professional values and the ability to make sound judgements based upon these in work-related situations'.
- Meta-competencies, concerned with the ability to cope with uncertainty, as well as with learning and reflection." (Delamare Le Deist & Winterton, 2005)

This approach has been adapted and used by many agencies and companies. In a research in sixteen organizations in UK, nine were using the functional competencies only two were using behavioral competency frameworks and five had combined the functional and behavioral approaches by introducing a hybrid model. (Delamare Le Deist & Winterton, 2005) This evidence suggests that the concept of competency in UK is also getting broader by *"underlying knowledge and behaviors rather than simply functional competencies associated with specific occupations."* (Delamare Le Deist & Winterton, 2005)

The Holistic Approach: The holistic or multi-dimensional approach describes competencies as a collection of individual competencies required from an individual – and organizational competencies required on the organization level to achieve the desired results (Straka, 2004). This approach was followed in France, Germany and Austria (Delamare Le Deist & Winterton, 2005). Most of the other European countries follows either the UK or the French or German approaches (Delamare Le Deist & Winterton, 2005).

In France, the competency movement started in the 80s and gained even a more prominent role in the 90s. The concept of competency in France focuses on the importance of vocational training for the individuals, combined with the collective role of the organization (Gilbert, 1996), in this way the influence of the McClelland (1973) approach is less prominent in this concept (Delamare Le Deist & Winterton, 2005).

The competency-based approach was initiated in the year 1993 by the government (Delamare Le Deist & Winterton, 2005), which was afterwards adapted by many companies and organizations (Durand, 2000). There has been since a broader movement and influence in France in connection with competencies, from the right to measure competencies, to introducing competency-based pay and in government initiatives in encouraging the adoption of competency-based initiatives in enterprises as well as educational institutions (Delamare Le Deist & Winterton, 2005). This approach is based on two directions, the individual centered approach, focused on the competencies that an individual must bring and a collective approach focused on the competencies required for the organizations (Haddadj & Besson, 2000).

Compared to the US approach, the French approach is more comprehensive by considering *"savoir (competences theoriques, i.e. knowledge), savoir-faire (competences pratiques, i.e. functional competences) and savoir-etre (competences sociales et comportementales, i.e. behavioural competencies)"* (Delamare Le Deist & Winterton, 2005). As Tremblay and Sire (1999) suggest there is a correlation between the UK functional competency and the French savoir-faire, as well as between the US approach and the French savoir-etre. And while in France the focus on personal or individual competencies has not been on the focus there is a tendency in using three dimensions of competencies as the concepts of knowledge (savoir and connaissance), a component based on experience (savoir faire or savoir agir) and a behavioral component (savoir etre or la faculte de s'adapter) which is also used and applied in some organizations (Delamare Le Deist & Winterton, 2005).

In Germany the first movement towards competencies was in the 80' with the introduction of key qualifications (Schlüsselqualifikationen) that included personal competencies as 'ability to act autonomously and to solve problems independently', 'flexibility', 'ability to cooperate', 'practical ethics and moral maturity' (Delamare Le Deist & Winterton, 2005). However as already mentioned, qualification focuses more on the ability to conduct a job, while competency is a broader concept including also general abilities and the capability to act in certain situations (Arnold, Nolda, & Nuissl, 2001).

The concept of competency was further adapted in 1996 in Germany by defining learning fields or competencies for every curricula (Delamare Le Deist & Winterton, 2005; Straka, 2004). Nowadays it is usual to define competencies in every curricula or training. A standard typology divides these competencies in *"elaborating vocational action competency (Handlungskompetenz) in terms of domain or subject competency (Fachkompetenz), personal competency (Personalkompetenz) and social competency (Sozialkompetenz)"* (Delamare Le Deist & Winterton, 2005). Furthermore the concept of domain competency is used that can be defined as *"Domain competency describes the willingness and ability, on the basis of subject-specific knowledge and skills, to carry out tasks and solve problems and to judge the results in a way that is goal-oriented, appropriate, methodological and independent."* (Delamare Le Deist & Winterton, 2005). The concept of competency in Germany has earn a high relevance.

In Austria, a similar concept as in Germany was followed (Delamare Le Deist & Winterton, 2005). The competencies are grouped in three main categories as cognitive competency (Sachkompetenz) that is described as having the knowledge, skills and ability to conduct a job and fulfil certain tasks; social competency (Sozialkompetenz), that is defined as the ability to deal in a social environment, communicate and cooperate with other; and the personal competency (Selbstkompetence) that comprises the ability to develop new skills, motivation, personal attitude etc. (Delamare Le Deist & Winterton, 2005)

This representation of the different developments of the concept through the years and in different research environments shows that apart from being very broad and widely discussed, the concept has different nuances and meanings depending on where and when it was used or applied. Therefore it is important for this research to exactly define how the concepts is used.

2.3.4 Competency Typologies

Researchers have tried to give a broader and more holistic view on the concept of competencies. Therefore a typology of competencies can be recognized in the literature. This typology comprises usually four categories (Figure 5) that slightly vary from one another, however the basic concept is the same. Solga, Ryschka, and Mattenklott (2011), Kauffeld (2006) and Sonntag (2004), propose four typologies as described below:

Functional Competencies: Functional or professional competencies describe specific abilities and professional skills, which are required to solve clear-defined tasks. This can for example include specialist knowledge in the application of IT-tools or industry- and market-expertise. Solga et al. (2011) and Delamare Le Deist and Winterton (2005) call these typology as functional competency, while Egeling and Nippa (2009) consider it as domain competency. However this is the same typology, describing the skills to perform a task.

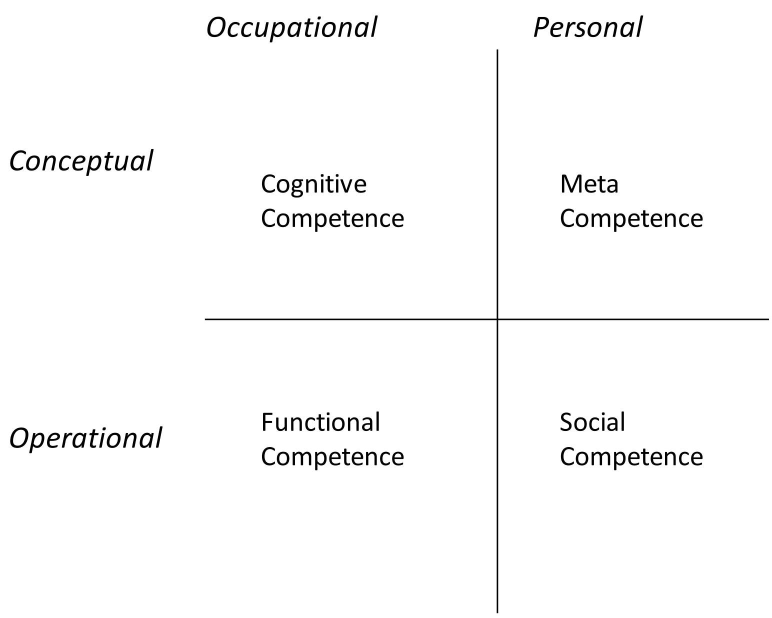

Figure 5: Typologies of Competency
(Source: Own Representation Based on Delamare Le Deist and Winterton (2005))

Methodological (Meta) Competencies: This typology describes flexible usable general planning- and decision-abilities, which qualify an individual to independently solve new and complex problems (Solga et al., 2011). Delamare Le Deist and Winterton (2005) define this as cognitive competency and relates it to the term of knowledge. Egeling and Nippa (2009) call it action related competency. In other words, it can be defined as general problem-solving-competency and adaptability. Specific competencies in this area are for example: problem-analysis, techniques for creativity or individual strategies for self-regulated learning.

Social Competencies: Egeling and Nippa (2009) calls it social or interpersonal competency, Delamare Le Deist and Winterton (2005) defines it also as social competency by including behavioral and attitudinal competencies in this typology. The social competency comprises communicative and cooperative abilities and skills, which qualify to realize individual or shared goals in an accepted way during a social interaction, are defined as social competencies (Solga et al., 2011). This includes for example communication skills, adaptability, conflict ability or assertiveness.

Self- or Cognitive Competencies: This area covers professional relevant attitudes, values and personal characteristics, which influence the professional self-reflection and the motivational and emotional direction of professional activities (Solga et al., 2011). Openness to new experiences, self-efficacy, optimism and pro-activeness are some of the included competencies. Egeling and Nippa (2009) defines it as personal competency while Delamare Le Deist and Winterton (2005) as meta competency that describes the ability to adapt the other competencies.

2.3.5 Competency Concept in the Context of this Thesis

An overview of the research on competencies was presented in the sections above. The term is broadly researched and discussed in the literature. Depending on the background of the studies, the culture or the period of the study, it takes different nuances and aspects into consideration. Therefore it is important to clearly define and limit how the term is going to be used in this work.

This study focuses on the individual as a key enabler for Industry 4.0. It does not focus on defining skills for a certain job profile, or collective competencies for a company. The goal is to define competencies for Industry 4.0 that could be adapted through an appropriate teaching/learning concept. Therefore the extended behavioral-based approach concept is applied, by combining it with domain related competencies since it offers the best fit for the purpose, by giving also the possibility to describe the relationship between competencies as constructs on the one hand, and psychological constructs such as motives and personality traits on the other (Kleindauer, Berkovich, Gelvin, Leimeister, & Krcmar, 2012). Furthermore, by defining the domain related competencies also the technology related aspects of the competencies are captured since technology is an important part of Industry 4.0 and should not be neglected.

"For this purpose the definition of Bartram et al. (2002), who defines competencies as: "sets of behaviors that are instrumental in the delivery of desired results or outcomes" (Bartram et al., 2002). In this sense "a competency is not the behavior or performance itself but the repertoire of capabilities, activities, processes and responses available that enable a range of work demands to be met more effectively by some people than by others" (Kurz & Bartram, 2002)." (Prifti, Knigge, Kienegger, et al., 2017)

2.4 Competency Model

"A competency model consists of desired competencies for a certain task and may also include a description of single competencies (Lucia & Lepsinger, 1999; Mirabile, 1997) as well as indicators to measure performance and outcome. This lists may include different detail levels and also describe relationships between the competencies. " (Prifti, Knigge, Kienegger, et al., 2017). Lucia and Lepsinger (1999) define it as *"[…] the particular combination of knowledge, skills, and characteristics needed to effectively perform a role in an organization"*.

To define competency models in research, various approaches are applied. Some authors focus on the literature and build their model based on existing competency models (Armstrong & Henry, 2009; Lee, 2010; McPherson et al., 2016; Salleh, Sulaiman, Mohamad, & Sern, 2015; Wiratmadja, Sunaryo, Syafrian, & Govindaraju, 2014), other follow guidelines (Armstrong & Henry, 2009), training programs (Cerinsek & Dolinsek, 2011) job descriptions (Cerinsek & Dolinsek, 2011), questionnaires with people that work in companies (acatech et al., 2016; Camuffo & Comacchio, 2005; Lans, Blok, & Wesselink, 2014; Yadav & Nalawade, 2012), expert interviews (Camuffo & Comacchio, 2005; Cerinsek & Dolinsek, 2011; Spencer & Spencer, 1993) or focus groups (Lans et al., 2014; Prifti, Knigge, Kienegger, et al., 2017). The models differ also based on the numbers of mentioned competencies, e.g. Jin, Lv, and Yan (2006) suggests a model containing only three competencies while the model of Erpenbeck and von Rosenstiel (2007) contains 64 competencies. The difference occurs also depending on the kind of competency model. Generic competency models, that describe areas or disciplines have a higher number of competencies and a detailed description of the single competencies (DOLETA, 2017; Erpenbeck & von Rosenstiel, 2007; Spencer & Spencer, 1993). These competency models have usually competencies of a more general nature. While job specific models have a lower number of competencies and less descriptions (DOAS, 2012). However the listed competencies in these models are more domain specific and concrete in relation to the mentioned job.

Further on, the competency models differ also based on the competency categories. Usually competency models cluster the competencies in competency categories (May & Ossenberg, 2014). Some authors develop competency models based on existing models and use the existing categories for this purpose (Jin et al., 2006; McPherson et al., 2016), while others (Armstrong & Henry, 2009; Lee, 2010) try defining their own categories, based on the competencies they have discovered.

May and Ossenberg (2014) e.g. define two competency categories that they consider similar as personal and professional competencies. While Armstrong and Henry (2009) categorizes the competencies in basic, vertical and horizontal competencies. A more usual approach is in categorizing competencies based on their content similarities (Derro & Jansma, 2008; Hu, Li, & Yu, 2011) and these models can be built hierarchy and have many categories that are hierarchically related to one another (Camuffo & Comacchio, 2005; McPherson et al., 2016).

However, apart from the differences in the structure of the competency models, there is a general understanding that a competency model is not cognatic but e.g. *„cluster of related knowledge, skills, and abilities that affects a major part of one's job […]"*(DOLETA, 2010).

2.4.1 Competency Model Categories

Competency models are a human resource tool for selection and recruitment, training and development, appraisal and succession planning (Lucia & Lepsinger, 1999; Rodriguez et al., 2002). Klug (2011) suggests four categories of competency models that include:

- Generic Competency Models
- Function- and Role-Specific Model
- Position-Specific or Single-Job Competency Model
- Company-Specific or Core Competency Model

While generic and role specific models are of a more generic nature, and can be applied in the context of Industry 4.0, the other Position-Specific Competency Models on the other hand are developed for specific job-positions (Klug, 2011; Lucia & Lepsinger, 1999) and the Company-Specific Models are used to ensure a common terminology of competencies within organizations (Klug, 2011). These two categories are very specific for certain jobs and organizations, therefore do not apply to the scope of this thesis and will be not further elaborated.

2.4.2 Generic Competency Models

Generic competency models are widely applied. As the name already states, these models describe a general accepted taxonomy or classification of professional requirements and behavior (Klug, 2011). These models can be applied in every branch, different levels of hierarchy as well as different job positions. Some generic models are limited and describe a small range of competencies. Jin et al. (2006) e.g. suggests a model for managers by focusing only on three competencies as „character competency", „interpersonal competency" and „problem-solving competency". Lans et al. (2014) suggest a model that combines organizational competencies with sustainability competencies. While Boyatzis (1982) analyses competencies for managers that are related to work performance. Lee (2010) develops a model for „Technicians and Professionals" based on the model developed by Spencer and Spencer (1993). This includes 12 competencies, a scale for the competencies as well as a description for each of them (Spencer & Spencer, 1993). Kim et al. (2007) do not generate a competency model per se, they however define which aspects should be taken into consideration while researching for key competencies. They suggests in researching and defining competencies in four directions as in School, University, Adults and Training (Kim et al., 2007).

Other generic competency models cover all aspects of competency. Wiratmadja et al. (2014) and Bohlouli et al. (2017) describe generic competencies however they have too less focus on personal related competencies as self-management. While Bartram (2005), DOLETA (2017) and Erpenbeck and von Rosenstiel (2007) provide a more holistic view on the competencies.

The DOLETA model presents a pyramid of nine hierarchical competencies. The first level in the basis of the pyramid describes competencies that can be applied in various areas e.g. working independently. Going higher in the pyramid the competencies get more specific. First there are the branch specific competencies, afterwards the competencies for a sector of a branch followed by competencies for a specific job on the top. The model defines 25 generic competencies. This model can be adapted from the bottom to the top for specific jobs. It is important that the generic competencies in the basement of the pyramid are always applied. An example of applying this model on a concrete job description is the „Advanced Manufacturing" (DOLETA, 2010).

The model suggested from Bartram (2005) contains three levels of hierarchy. On the last and most detailed level there are 112 competencies („component competencies"). These competencies describe the behavior on the job. The competencies are grouped in the next level in 20 competencies, called competency dimension. The last level covers eight competency factors that define the basic competencies and behaviors that are expected on the job (Bartram, 2005). This model can be adapted and applied for specific areas, disciplines and branches. Prifti, Knigge, Kienegger, et al. (2017) e.g. applied this model for developing a generic model for competencies in the area of Industry 4.0.

Erpenbeck and von Rosenstiel (2007) define 64 competencies in four categories: personal, social-communicative, method and action competencies. This is similar to the competency typologies defined in above. They describe typical behaviors for every competency. This competency model is however in German language, it is in this way adapted for the German market and culture.

2.4.3 Function and Job-Specific Models

The function or job-specific competency models describe a universal taxonomy of the behavior and the requirements within a described functional area. Persons, who are operating in this area (for example executives or managers) have to meet the requirements in order to be successful (Boyatzis, 1982; Klug, 2011).

These models focus on a specific job, therefore they have a high number of specific competencies and a low number of generic competencies. E.g. Armstrong and Henry (2009) present a model for system engineers. The model consists of specific competencies with regards to the development and operation of complex technical systems. Additionally the model contains five more generic competencies. However the generic competencies are somehow related to the job description, e.g. mathematical knowledge. Derro and Jansma (2008) and Jansma and Derro (2007) also describe competency models for system engineers. Their models include three categories of competencies as professional, organizational and personal competencies. Cerinsek and Dolinsek (2011) also propose a job specific competency model for manufacturing. Similar as the models mentioned above this model contains specific competencies as well as generic competencies that are more related to the concrete manufacturing process.

However not all the models in this category are so specific. Hu et al. (2011) and Yadav and Nalawade (2012) describe competency models for employees in research and development and engineers. In both cases they have a high number of generic competencies compared to the ones mentioned above. Yadav and Nalawade (2012) e.g. mentions the same number of specific as well as generic competencies by clustering these in the categories as mentioned by May and Ossenberg (2014). The reason why these models contain more generic competencies is that they describe a broader function area compared to the models above describing a specific job. A difference is also in comparison of operative and less operative jobs. While models for operative jobs contain a higher number of specific competencies, the less operative jobs contain more generic competencies. E.g. Camuffo and Comacchio (2005) describe competencies for managers, and the model contains more generic competencies than specific ones.

A third group in this kind of competencies describes more generic models. E.g. the model for the administration (DOAS, 2012) contains some administrative related competencies followed exclusively by generic competencies. For each of these competencies there are several level and behavioral approaches that are described in the model. This model is therefore very similar to a generic competency model, however it contains only 18 competencies and also is adapted to the needs of the administration by making it more specific. McPherson et al. (2016) and DOLETA (2010) apply both a generic competency model and add to it some domain related competencies.

By comparing the models in this category it is clear that job specific models contain more specific competencies compared to generic models. However the number of specific competencies is lower when the model gets more specific by describing a certain area of discipline e.g. A further factor is the hierarchy level of the job which is being described by a model. The higher the hierarchy level of a model the more generic the competencies get.

2.4.4 Competency Models for Industry 4.0

Since one of the goals of this thesis is also to define a competency model for Industry 4.0, existing models from the literature were also. A total of four Industry 4.0 related competency models could be extracted in the literature. These models define their competencies based on the literature as Erol et al. (2016) and Prifti, Knigge, Kienegger, et al. (2017), focus groups (Prifti, Knigge, Kienegger, et al., 2017), as derivation from tasks of the future (VDI, 2015) and as questionnaire in companies (acatech et al., 2016).

acatech et al. (2016) follows a holistic/multi-dimensional approach by defining competencies on personal level, meaning the competencies that employees should bring, and on organizational level, meaning collective competencies that should be available in companies (acatech et al., 2016). In both groups there are three categories as technology/data related competencies, process and customer related competencies and individual/personal competencies (acatech et al., 2016). These competencies are specifically defined for Industry 4.0, this means that often generic competencies that are not Industry 4.0 specific but still relevant for Industry 4.0 as teamwork are not part of this model (Suleman, 2016). This competency model is therefore not suitable for individuals (acatech et al., 2016). The focus of this survey was also the automobile industry (acatech et al., 2016), meaning that further competencies for other branches are not considered. The competencies are used in a form that is defined from acatech et al. (2016) and has no similarities to existing competency models, therefore it is difficult to apply this model or compare it to others (May & Ossenberg, 2014).

Erol et al. (2016) conducts a literature review and uses the classification of Erpenbeck and von Rosenstiel (2007) meaning they use personal, method, social and action competencies as categories. This model covers more competencies then acatech et al. (2016), since it goes in a deeper level of detail by defining also sub-competencies. Erol et al. (2016) cover a high number of competencies however some generic competencies as decision making or responsibility are still missing. They differentiate between competencies that are necessary for everybody and competencies for workers, engineers and managers (Erol et al., 2016). In the method competencies Erol et al. (2016) put the focus on the competencies for the production and they also mention that further competencies might be necessary (Erol et al., 2016). It means that this model is more suitable for the production and has no branch crossing nature.

The model suggested by VDI (2015) is different from the two models above in many aspects. The model contains only two categories, personal and technical competencies. This includes the individual and domain related competencies as compared to May and Ossenberg (2014). Further on, the competencies are divided in three priorities if they are necessary or optional. Their mentioned competencies are similar to the competencies mentioned by Erol et al. (2016). This model defines competencies only for workers in Industry 4.0, while competencies for managers and academics are not part of the model.

The three models described in this paragraph are all related to Industry 4.0. However these models differ from one another in many aspects. The number of defined competencies varies from model to model. Further on, by being specifically defined for Industry 4.0, these models miss sometimes generic competencies that are not Industry 4.0 specific but still relevant for Industry 4.0 and therefore important.

2.4.5 The Competency Model Concept in the Context of this Thesis

After analyzing the different competency models below, the main aspects needed for the purpose of this thesis can be extracted. While defining a competency model for Industry 4.0, it is important to include generic as well as domain specific competencies. Furthermore the model should provide an adequate level of detail and reflect the correlation and interdependencies between the competencies. It should cover a high number of competencies and comprehend also generic competencies that are not only Industry 4.0 specific. Therefore for the purpose of this thesis the SHL Universal Competency Framework (UCF) is applied. CEB Inc. (2016)[11] offers the SHL UCF[12] (Bartram, 2005) as a generic foundation for building competency models. This behavioral-based framework was derived by analyzing practitioners and academic approaches.

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[11] CEB Inc. is a global best practice and insights technology company providing services to businesses worldwide (CEB Inc., 2016).

[12] SHL Universal Competency Framework (UCF) presents a state-of-the-art perspective on competencies and is used worldwide from well-known companies as e.g. Coca Cola. It is offered by CEB Inc (see above) (Bartram, 2005).

"Choosing this existing framework offers many advantages. It offers a state of the art structure for competency modeling by not only listing the competencies but also showing the relationships between them. The framework is used both in research and practice, so our work makes a two-fold contribution. Since many companies apply it to build their competency profile, it offers the potential to compare our results with industry profiles in practice. " (Prifti, Knigge, Kienegger, et al., 2017).

3 A Competency Model for Industry 4.0

3.1 Introduction

The goal of this part of this thesis is in defining competencies for working in Industry 4.0. As defined in the previous chapter of this thesis the behavioral-based approach regarding competency analysis will be followed, since the goal is to focus on the individual as a central component for enabling Industry 4.0. Therefore the definition of Bartram et al. (2002) is applied that considers competency as: *“sets of behaviors that are instrumental in the delivery of desired results or outcomes”* (Bartram et al., 2002) or *“a competency is not the behavior or performance itself but the repertoire of capabilities, activities, processes and responses available that enable a range of work demands to be met more effectively by some people than by others”*[13] (Kurz & Bartram, 2002).

Industry 4.0 is accompanied with many new technologies as sensors, automation, networks or cyber physical systems. The mastering of these technologies requires a whole set of new competencies. Through the emerging of these technologies also entire business models will arise, with new products and new delivery opportunities. Furthermore Industry 4.0 will have an impact on actual business models by affecting and changing whole work processes, through automation and technology. It means that Industry 4.0 will cause a significant change in the work environment (acatech et al., 2016). The model of work organization will transform due to the disruptive nature of emerging technologies and modified structures for communication and collaboration (Zinn, 2015). Processes will become interconnected and more complex and the technical, organizational and social spheres of work activities will overlap, in this way the way we work will be one of the most affected changes in Industry 4.0 (Gebhardt et al., 2015). Work content, work processes and work environment will be transformed (Kagermann et al., 2013). Industry 4.0 does not affect only technology and production, but the way of work in all its dimensions (BMAS, 2015).

This transformation of the work environment will change job profiles and requires therefore new competencies for the employees (acatech et al., 2016; Kagermann et al., 2013). Many researchers and practitioners agree that defining and analyzing competencies for Industry 4.0 is a crucial aspects for succeeding in Industry 4.0. Kagermann et al. (2013) pointed the qualification of employees with the right competencies as one of the key success factors for Industry 4.0. A wide range of skills and competencies are the main requirements for the implementation of Industry 4.0 (Smit et al., 2016). Companies will need to extend their competencies in order to optimize their businesses (McKinsey, 2015). In order to successfully get through the digital transformation of Industry 4.0, a clear definition of the competencies for Industry 4.0 is needed

[13] A discussion why this competency definition is applied in the context of this thesis is provided in chapter 2.3 Competency.

(Jaschke, 2014; Richert et al., 2016; Richter et al., 2015) and the further challenge lies in preparing students and workforce in adapting these competencies (Richter et al., 2015).

Erol et al. (2016) propose competencies derived from the literature by offering a scenario-based learning concept for students. acatech et al. (2016) analyzed German companies and propose a set of competencies divided in two areas, competencies that the companies should master and competencies that the employees should adopt. Windelband (2014) analyses the transformation of the job profiles for labor employees by also mentioning relevant competencies that they should possess. While Gebhardt et al. (2015), Guo (2015), Stocker et al. (2014) and Richter et al. (2015) analyze work in Industry 4.0 by mentioning competencies that will become relevant. In Industry 4.0 work profiles that require an academic education will earn on significance, while labor workforce will be mostly replaced by automated processes. Therefore, competency models focused on different aspects of the academic education should be defined. Academic education is however very broad. And although Industry 4.0 will have an impact also on our daily lives, there are certain professions that are more directly connected with the industry that will be more affected that others. Industry 4.0 will be accompanied by the use of different manufacturing machines that will require competency profiles for engineers. IT will earn a role in programming these machines and designing new IT architectures, which requires new competencies for computer science (CS) professionals. These changes in production will lead in new IT processes and structures and also a different way of managing people which requires different competency profiles for IS and economic professionals. Therefore Prifti, Knigge, Kienegger, et al. (2017) suggests that a part of the most affected professions for Industry 4.0 will be Engineering, IS and CS.

Therefore in the focus in this chapter lies in defining competencies for Industry 4.0 as a challenge of our economy, by focusing on the professions that will be mainly affected by Industry 4.0 as Engineering, IS and CS. To define the competencies, first a literature review is conducted to extract competencies for Industry 4.0. A literature review is considered as a first step in exploring existing knowledge about a topic, in order to be able to further explore it (vom Brocke et al., 2009). However since literature on the topic is scarce (Prifti, Knigge, Kienegger, et al., 2017), focus groups as an empirical research method were applied in order to extend the results of the literature with expert opinions and also evaluate these results. At the end a competency model including the three mentioned professions, based on the SHL UCF is developed.

3.2 Method

3.2.1 Literature Review

3.2.1.1 Theoretical Foundation

Literature review is an established research method described from many authors. Baker (2000) considers a literature review as an essential first step and foundation when undertaking a research project, while vom Brocke et al. (2009) emphasize that knowledge is often created in the process of interpreting and combining existing knowledge. Hevner et al. (2004) also underline that rigor is derived from an effective use of existing knowledge base. Levy and Ellis (2006) and Webster and Watson (2002) also argue the importance of literature review with the special focus on information systems. As a research method, it is important to follow a clear and transparent way for conducting a literature review in order to receive plausible and scientifically valid results. By recognizing the importance of structured literature reviews, different authors already described methods (Baker, 2000; Webster & Watson, 2002) and suggested frameworks for conducting a literature review (Levy & Ellis, 2006; vom Brocke et al., 2009).

Webster and Watson (2002) highlight the importance of literature search. They recommend focusing on leading journals, and conduct a keyword search and also forward and backward search of the literature. The structuring of the review is considered another important step. In their paper, Webster and Watson (2002) suggest a high structured approach, which could be concept- or author-centric to represent the results of a literature review.

For all these reasons, to set a theoretical basis for this research, the first chosen research method is literature review. In the presented work the approach described by Webster and Watson (2002) is applied, since this work has a focus on information systems and describes an approach that was adapted for this field.

3.2.1.2 Approach

In this step of the work a systematic literature review that offers a rigorous view of existing research results (vom Brocke et al., 2009) was applied. By following the recommendations of Webster and Watson (2002), a concept centric approach was followed. The goal of this step of the work was to identify, classify and summarize competencies about Industry 4.0 presented in the literature.

The review scope: By following the guidelines of Webster and Watson (2002) and vom Brocke et al. (2009) the review scope needs to be defined. As the literature review often begins with initial ideas or questions that reveal a specific research problem (Boell & Cecez-Kecmanovic, 2014), it is crucial to define an appropriate scope at an early stage of the review. For defining the review scope the Cooper (1988) taxonomy was applied. Cooper (1988) suggests six elements to be taken into consideration while defining the review scope as presented in Table 2. After analyzing each element with regards to the topic, the research question that sets the review scope for the research purpose was defined at this step of the work: *“What competencies are critical for job positions that require higher education for effectively and efficiently performing in* Industry 4.0*?”*

Table 2: Definition of Review Scope
(Source: Own Representation Based on Cooper (1988))

	Meaning	Definition in the Context of this topic
Focus	The *focus* of the literature review reflects the material that is of fundamental interest for the reviewer. The	In terms of this research, the *focus* lies in the research outcomes namely a list of competencies for working in Industry 4.0.

	focus concerns the research outcomes, research methods, theories, and practices or applications.	
Goal	The *goal* reveals what the author intends to accomplish. Three main *goals* for the literature review are: Integration, criticism, and identification of central issues.	In terms of the current research, the *goal* is to integrate the competencies from different sources that are important for working in Industry 4.0.
Perspective	The p*erspective* shows the influence of the reviewer's point of view on the discussion of the literature. The reviewer might take a role of a neutral person or espouse of position.	In terms of the work, the neutral representation is chosen, since the goal lies in the integration and identification of competencies for Industry 4.0 without the intention to criticize the available works.
Coverage	The *coverage* describes the way the review searches the literature and sorts out the relevant contribution. Cooper (1988) distinguishes between four types of *coverage*: Exhaustive, exhaustive with selective citation, representative, and central or pivotal.	In terms of the thesis, I applied an exhaustive search of the literature because due to lack of reliable sources on the topic. However, the relevance of the topic as well as time range was considered.
Organization	The o*rganization* describes how the review is organized. The way the review might be organized varies from historical, to conceptual, to methodological.	The literature review was conducted with the use of conceptual *organization* meaning that the identified criteria are listed according to the available concepts.
Audience	The *audience* reveals the target group of the review. The *audience* might include specialized scholars, general scholars, practitioners or policy makers, and general public.	The results of this review are relevant from a research point of view, since they offer a work gathering all competencies on Industry 4.0. It has also a relevance for educators from the practical point of view and can be used as a basis for designing competency-based curricula.

Conceptualization of the Topic: After the scope of the literature review is defined, a wide observation of the available information about the topic and possible areas where the new knowledge might be applicable, should be started (Torraco, 2005). It is necessary to identify sources that contain key issues or concepts about the relevant topic. Moreover, working definitions of the key terms should be available (vom Brocke et al., 2009). In order to identify the key concepts, vom Brocke et al. (2009) proposes to apply a concept mapping. The concept mapping helps to create a complete overview over the search terms (including synonyms), that can be used in the literature search. The main goal of the concept mapping is to help a researcher to understand the topic in a proper way. This understanding might vary in time as the research advances.

For conceptualizing the topic (Figure 6), two-fold literature was taken into consideration by separating the research scope “Competencies for Industry 4.0” in two parts. It consists of the parts “Competencies” and “Industry 4.0”. For each of these parts or concepts it was searched in the literature in order to define synonyms or similar concepts for conceptualizing the topic. By analyzing literature as Kagermann et al. (2013) or acatech et al. (2016), the following concepts with regards to Industry 4.0 could be defined: “Industrie 4.0”; “Industry 4.0”; “Digital Transformation”; “Internet of Things”; “IoT”; “Cyber Physical Systems”; “CPS”. Further it was searched in competency related studies as Bartram (2005) or Delamare Le Deist and Winterton (2005), and similar concepts were defined as: “competence”, “competency”; “skill”; “knowledge”; “attitude”; “ability”; “value”; “education”.

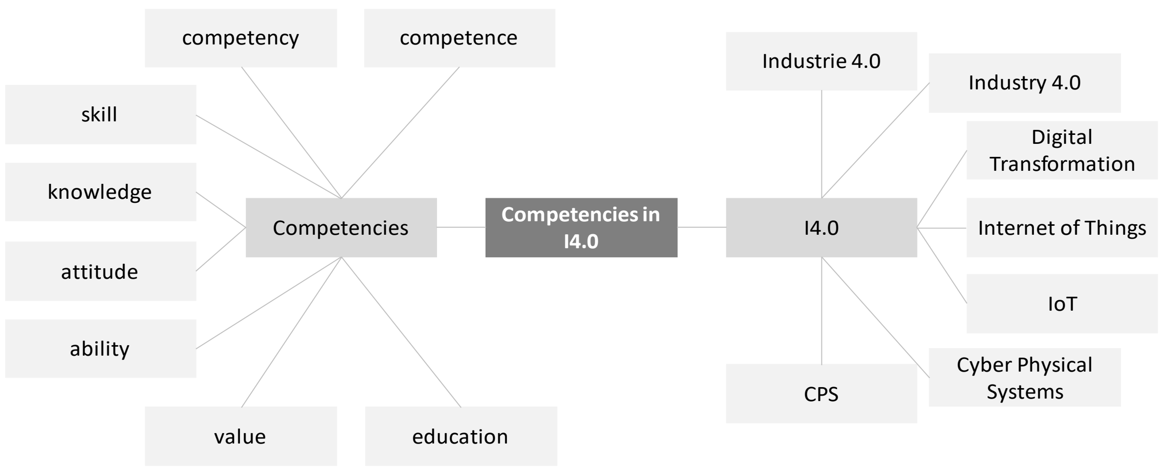

Figure 6: Conceptualization of the Topic (Source: Own Representation)

Literature Search: The literature review builds a theoretical foundation for the work, therefore it has to prove its quality. Webster and Watson (2002) recommend to conduct the literature search in the leading journals and eminent conferences. Therefore in order to cover the leading journals and conferences, a database search was applied.

Industry 4.0 has an influence on the disciplines as IS, Economics, IT and Engineering that also create the target group of this thesis. Therefore the database search included databases as Institute of Electrical and Electronics Engineers (IEEE) Xplore Digital library, Association for Computing Machinery (ACM) Digital library, Springer and EbscoHost[14]. Levy and Ellis (2006) consider numerous of ACM and IEEE journals and ACM and IEEE conferences as highly ranked and reliable sources. Further libraries as Springer and EbscoHost were chosen because they also covers topics that are outside the IS field: Economics, information and knowledge management, engineering, etc. Many Education outlets including conferences like EDUCON,

[14] The used EbscoHost Databases are: Business Source Premier, EconLit, Information Science & Technology Abstracts, Education Source, ERIC, Business Source Complete

REV, ICL, or Frontiers in Education that are often target outlets for publishing competency studies were also covered with this choice of databases.

Additionally a Google Scholar search was conducted to identify prominent articles, which are relevant for the conducted research but were not published in the reviewed journals. In the Google Scholar search, the results were sorted by relevance and only the top-30 of them were considered. By Google Scholar in the search, the probability not to overlook possibly relevant sources is higher. The reason for it lies in the interdisciplinary of IS (Webster & Watson, 2002).

In the first search a total of 3363 hits over all the databases were found. A first screening over all these hits was conducted by analyzing the title and abstract. After this screening a total of 26 articles considered relevant regarding the topic were selected. These articles were afterwards read and analyzed in a second screening where the whole articles were read. Only articles where explicit competencies are mentioned were chosen. At the end a total of 16 articles that mention competencies for Industry 4.0 or similar concepts such as IoT, were selected for further analysis. As recommended by Webster and Watson (2002) a backward forward search was also conducted where one additional article could be added to the list of hits.

The topic is relatively new, so that little research exist (Prifti, Knigge, Kienegger, et al., 2017). However the topic has a high practical relevance, therefore many practitioners has published with regards to the topic. In order to complete the results and have a more complete set of competencies, the recommendations of Levy and Ellis (2006) were followed by analyzing additionally practitioners' texts. For this purpose the same search strategy as for the search and analysis of the scientific articles was applied. The same keywords were used for the search string, while the search was conducted by analyzing articles through Google search where the top ten hits for each search tuple were analyzed. After conducting a first and second screening for the results of the Google search as also conducted before, a total of ten practical articles were considered as relevant and added to the articles to be analyzed. These hits included practical articles, white papers and reports that propose competencies for Industry 4.0 and similar concepts as the IoT, Digital Transformation, etc.

Going backward and forward by reviewing the citations and considering similar citations, resulted in one further source. Backward and forward search is introduced by Webster and Watson (2002) as an important step in the literature research technique. Backward citation contains sources that were published earlier. Backward citation helps to learn more about the origin of the topic. Forward citation means newer sources – it helps to extend the knowledge of a particular topic (Levy & Ellis, 2006).

At the end of the search a total of 27 articles including scientific papers and practitioners' publications was reached. The whole search process is described in Figure 7.

The described process was conducted in August of 2016 where the results were published in the conference Wirtschaftsinformatik 2017 in St. Gallen. Since this work is submitted in 2018, an additional search was conducted including articles that were published from August 2016 to July 2018 where the thesis was last updated. This new searched followed the same approach as described above and its goal was to extend and complete the presented results. Through this search additional 16 papers could be added to the list.

In comparison with the first search in 2016 the second search delivered a relatively high number of results and related publications for the short period of thime. This shows the relevance that this topic presents in praxis and research.

Literature Analysis and Synthesis: After creating a basis for answering the first research question, the selected articles have to be analyzed and synthesized (vom Brocke et al., 2009). For the literature analysis and synthesis a concept-centric approach, described by Webster and Watson (2002) was applied.

In this step of the work, competencies for working in Industry 4.0 that are currently available in the literature were identified. However, the list of competencies is never complete and can be further supplemented.

“A review succeeds when it helps other scholars to make sense of the accumulated knowledge on a topic” (Webster & Watson, 2002). In terms of the presented research, all the available competencies for Industry 4.0 available in the literature were gained.

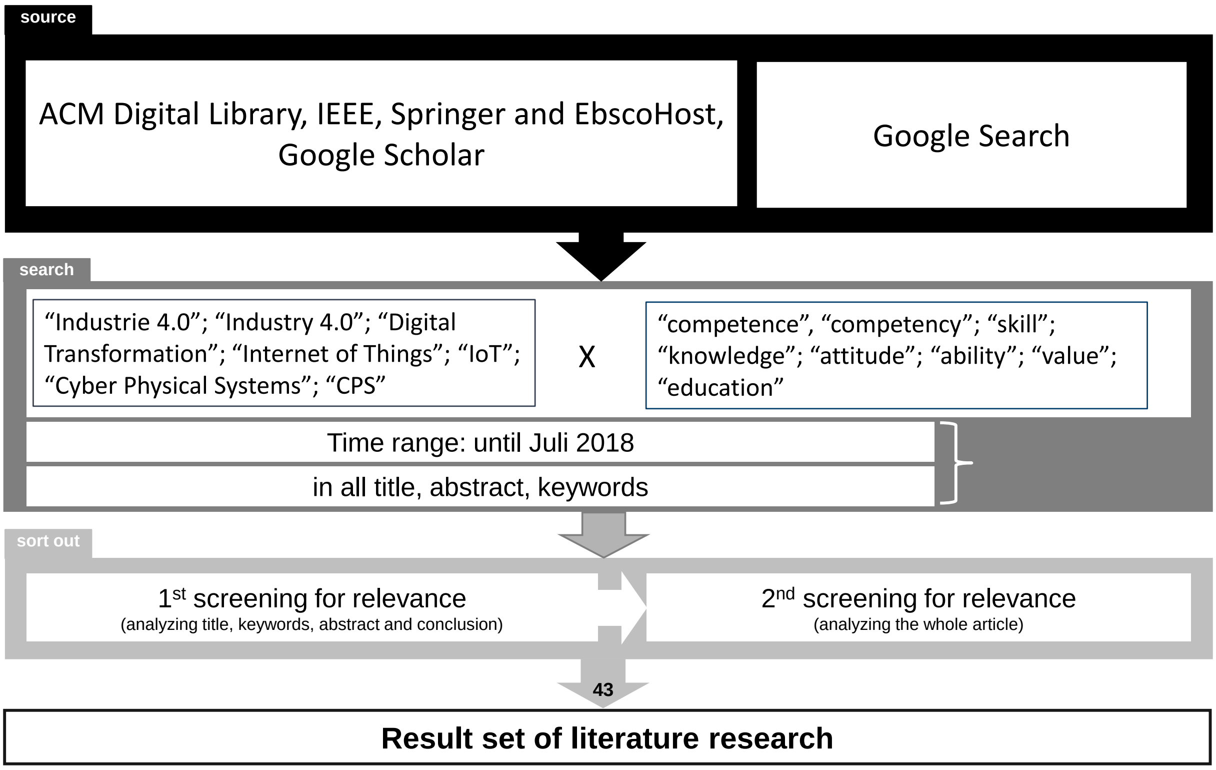

Figure 7: Literature Review Research Model
(Source: Own Representation Based on Heininger, Wittges, and Krcmar (2012))

3.2.2 Focus Groups

3.2.2.1 Theoretical Foundation

Based on the literature review 64 competencies could be identified. However as mentioned before the literature on the topic is rather scarce. Bearing in mind the complaints of Webster and Watson (2002) on the lack of theoretical knowledge and the fact that theoretical knowledge often differs from the practical experience (Glaeser & Laudel, 2010), the theoretical results from the literature were extended with results from a practical perspective.

So in order to evaluate the results and be also able to further extend them, an empirical research method: focus group interviews, was applied.

"Focus groups are group discussions organized to explore specific set of issues such as people's views and experiences" (Kitzinger, 1995). It is mainly a sociologist research method that has found application in many disciplines as many other qualitative methods (Billson, 1989). In education, focus groups have also been widely applied to foster various topics and develop further ideas (Brotherson & Goldstein, 1992; Gilflores & Alonso, 1995; Lederman, 1990).

Focus groups are appropriate for gathering in-depth information from past, current, or potential consumers, program participants, voters, organization members, etc. (Krueger & Casey, 2014). It uses a certain group dynamic and in comparison to interviews it can be a more effective technique for idea generation Fern (2001). Carey and Smith (1994) talked about the so called group effect, it means that a certain synergy arises between the participants and they complement and extend each other ideas. This offers the possibility for a more valuable data collection (Krueger & Casey, 2014; Morgan, 1996). The researcher has the possibility to ask the participants themselves for a comparison between one another and can encourage a certain discussion rather than having to agree on anonymous data from past interviews (Morgan, 1996).

By analyzing these advantages, focus group are a suitable research method for this case. They offer the possibility to extend and evaluate the results of the literature. Through the discussion it is possible to gather also further information about a relatively new topic. Furthermore Krueger and Casey (2014) mention the costs of gathering focus group participants as one of the weaknesses for conducting focus groups. In the presented setting, due to some trainings that were being held on site at the university, a setting where many experts were present was available, so that this weakness could be overcome easily.

3.2.2.2 Approach

3.2.2.2.1 Data Collection

Scope and target group: The scope of the focus groups was to verify the competencies from the literature as well as to extend and further refine them. Therefore, it was important in choosing the right target group to be part of the focus group interviews. Glaeser and Laudel (2010) outline the importance of the partner's selection for empirical data collection. They are convinced that the right selection of the partners is crucial for the high quality of gathered information (Glaeser & Laudel, 2010). The identification of the experts happened by answering the following questions, pre-defined by Glaeser and Laudel (2010): Who has the relevant information? Who is able to provide the most precise information? Who might be willing to provide the necessary information? Who of the informants is available?

For these purpose the focus groups were conducted with people from academia who have had also previous experience in industry. The reason why these were the right partners is because by having previous experience they were aware of the importance of competencies for the job. Since they were active in education, they had a better understanding of modern concepts that are relevant for theory and practice and they were familiar with topics as Industry 4.0 and competency building since it is widely discussed in academia nowadays. Furthermore, since all the participants shared the same job and followed a similar career path, they shared a similar mindset by making it easy to create a familiar and dynamic atmosphere for the focus groups as recommended by Krueger and Casey (2014). A further reason for the partner selection from academia was that the competencies being defined should be used as a basis for developing university education concepts and curricula. In this situation, it was helpful to conduct focus groups with participants that were active part of the university education.

Planning the focus groups: Before starting the focus groups a semi-structured guideline as recommended by Glaeser and Laudel (2010) was created. The guideline gives a structure and a plan to the communication process and it makes sure that all the relevant data necessary for the research is collected.

The guideline should be created in advance but neither the formulations nor the order of the questions have to be predefined (Glaeser & Laudel, 2010). The questions should offer the participants the possibility to answer based on their knowledge and experience however it should not provide the respondents with the opportunity to answer in a predefined way (Glaeser & Laudel, 2010).

The semi-structured guideline gives a structure to the data collection process and helps the researcher in conducting the interview. Through the same structure between different focus groups, it creates also a comparison basis for the data analysis phase.

The Critical Incident Technique (CIT) (Flanagan, 1954; Koch et al., 2009) for the focus groups guidelines was applied in order to derive the competencies for Industry 4.0. The CIT is used to describe job requirements for a job and for task analysis. Since the discussion is focused on job orientation of the future, top down, future oriented critical incidents were applied (Koch et al., 2009). The participants were presented with typical work scenarios and products of Industry 4.0. Then questions were asked about the competencies that employees should bring in Engineering, IT and IS to efficiently work in these scenarios.

Conducting the focus groups: The participants of the focus groups were informed before about the topic and goal of the focus groups. The focus groups were conducted by the same researcher in all the cases, in order to ensure a comparability of the findings. Furthermore, the same guidelines were used. During the focus groups the general rules of Glaeser and Laudel (2010) were applied.

A total of four focus groups with members from academia including teachers, professors, lecturers and researchers were conducted. The duration of the focus groups varied from 30 – 60 minutes. All the focus groups were recorded in order to assure that the whole discussion is covered. To ensure that the recording was flawless an assistant was present during the focus groups that was responsible for recording the discussion and helping the conductor of the focus groups. In this way the moderator could focus only on the discussion and moderate it accordingly.

As recommended by Glaeser and Laudel (2010) the moderator also made some follow-up questions during the discussion, or encouraged the participants to further talk about a topic.

3.2.2.2.2 Data Analysis

In order to prepare the material for analysis, it should be transcribed from oral speech to written text (Kvale, 1996). This stage is a prerequisite for the analysis (Bogner, Littig, & Menz, 2009). By using the recordings of the focus groups, they were transcribed by creating simple text documents with the information from the discussions. Each discussion was transcribed and analyzed separately. Three of the focus group discussions were conducted in English while one was conducted in German. The reason is that the group where it was conducted in German was a German speaking group. Usually a group can easily express itself in its native language, and it also maintains the group dynamic which is important for the focus groups. Since the moderator of the focus groups was fluent in both languages, the focus group was conducted and transcribed in German. However for the purpose of this thesis the citations are translated into English from the author.

After the focus groups were transcribed, the transcripts were imported in the software MAXQDA[15]. MAXQDA is a software developed from the company VERBI and is used for qualitative data analysis as well as mixed method analysis for research and business. Since the focus groups represent qualitative data, this was a suitable software for this purpose.

The four transcripts were imported in MAXQDA and separated in analysis units. So each sentence that represented a new idea or topic was separated as a single analysis unit. In each of these analysis units, information that represented competency was separated. For the coding an inductive and deductive approach were combined. This means that the competencies from the literature delivered the initial codes. If in the separated analysis unit one of these competencies was discussed, e.g. directly mentioned or thermalized than it was coded directly with the code from the literature. Nevertheless it was also aimed to extract new codes, so if a new competency could be recognized, that was not available in the codes from the literature, then it was inserted as a new code. In this way the results of the literature could be evaluated. It means that if a competency from the literature was mentioned in the focus groups, than this counted as an evaluation, on the other side, new competencies that were not mentioned in the literature could be added to the list of competencies available and complete the results with empirical data in

[15] http://www.maxqda.de/

this way. In Figure 8 the whole process of extracting the relevant information from the transcripts is visualized, while in Figure 9 an example of the extraction and coding is shown.

The process of coding was conducted from the author of the thesis who also moderated the focus groups and had a clear understanding of the discussions as well as could remember parts of it. To verify the results it was separately and independently coded again from a research assistant. In this way it could be assured that the codes were not biased. If there were results that were not conclusive between the two coding procedures, then the two coders discussed a consensus.

Certain competencies were mentioned different times, either during the same discussion, or between different focus groups. In this case all the mentioning were put under the same code and could be counted by quantifying in this way the qualitative data. This quantification is discussed in the section about the focus group discussion, where the most mentioned competencies are considered as more important and highly ranked.

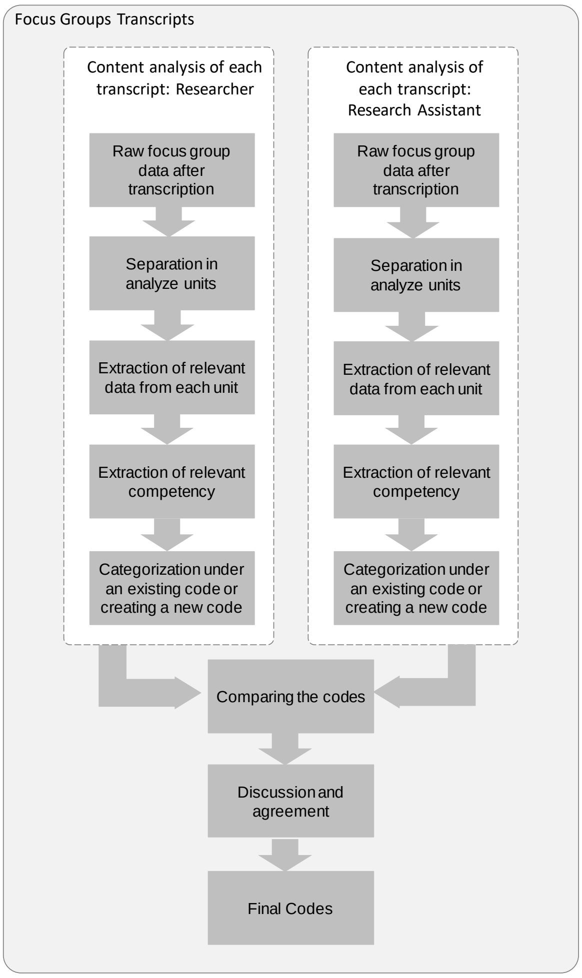

Figure 8: Analysis Steps of the Focus Groups
(Source: Own Representation)

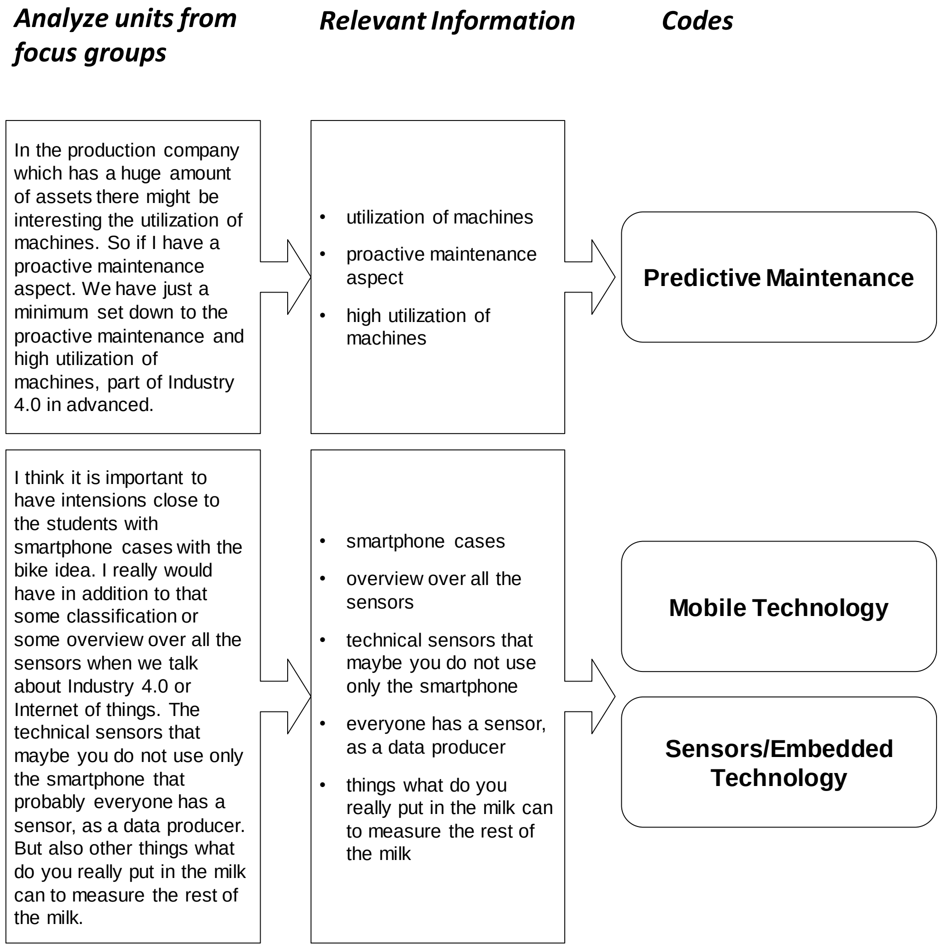

Figure 9: Extraction of the Competencies from the Focus Group Transcripts (Source: Own Representation)

3.3 Developing the Model

3.3.1 The SHL Competency Framework[16]

The SHL Competency Framework has been developed based on competency approaches from research and practice (Bartram, 2005). The competency framework is built on the definition of Bartram et al. (2002) that is also used throughout this thesis that describes competencies as *"sets of behaviors that are instrumental in the delivery of desired results."* It describes a framework that provides a basis for developing competency models that can be used to describe people behaviors on a job. It is widely used in practice and many companies use it to describe their competency models for specific job positions. The SHL Competency Framework offers a behavioral approach to competency modeling by focusing on the individual and considering com-

[16] A discussion why this model is considered suitable and used in this thesis is provided in 2.4 Competency Model

petencies of behavioral nature, meaning an individual can learn and adopt them unlike e.g. personality. This model serves the purpose of this thesis the best, since the focus in this thesis is on describing competencies for individuals and focusing on their behavioral nature.

This framework is composed of a three tier structure: the great eight, the competency dimensions and the competency components. The tier of competency components describes 112 specific competencies, and describes the structure and relationship between competencies by mapping them to the second tier of 20 broader competency dimensions, which are afterwards further categorized and put in a relationship by the eight great eight competency factors. This great eight factors are described in Table 3. This structure gives the possibility to extract sets of competencies that are needed for a specific model. The full competencies included in the competency model are provided in Table 4.

Table 3: The Great Eight Competencies
(Source: Own Representation Based on CEB Inc. (2016))

SHL's "Great Eight" Competencies	
Leading and Deciding	Takes control and exercises leadership. Initiates action, gives direction, and takes responsibility.
Supporting and Cooperating	Supports others and shows respect and positive regard for them in social situations. Puts people first, working effectively with individuals and teams, clients, and staff. Behaves consistently with clear personal values that complement those of the organization.
Interacting and Presenting	Communicates and networks effectively. Successfully persuades and influences others. Relates to others in a confident, relaxed manner
Analyzing and Interpreting	Shows evidence of clear analytical thinking. Gets to the heart of complex problems and issues. Applies own expertise effectively. Quickly takes on new technology. Communicates well in writing
Creating and Conceptualizing	Works well in situations requiring openness to new ideas and experiences. Seeks out learning opportunities. Handles situations and problems with innovation and creativity. Thinks broadly and strategically. Supports and drives organizational change.
Organizing and Executing	Plans ahead and works in a systematic and organized way. Follows directions and procedures. Focuses on customer satisfaction and delivers a quality service or product to the agreed standards.
Adapting and Coping	Adapts and responds well to change. Manages pressure effectively and copes well with setbacks.
Enterprising and Performing	Focuses on results and achieving personal work objectives. Works best when work is related closely to results and the impact of personal efforts is obvious. Shows an understanding of business, commerce, and finance. Seeks opportunities for self-development and career advancement.

The competency framework distinguishes competencies as desirable sets of behaviors. The SHL competency model is not about knowledge or skills. Such models are often referred as competency models. However competency goes beyond knowledge or skills, since it describes the ability to demonstrate job-related knowledge and skills. The competency concept also includes in assessing the level of these knowledge and skills in relation with some predefined outcomes and some defined sets of work performance standards or requirements. Competency, in relation to occupational standards based qualifications, has been defined as *'the ability to apply knowledge, understanding and skills in performing to the standards required in employment. This includes solving problems and meeting changing demands"* (Beaumont, 1996). This underlines that competencies go beyond the concept of knowledge and skills and define the level of the application of the knowledge in relation to predefined standards. Furthermore, knowledge and skills are specific for a certain job or position in an organization, and the variety of knowledge and skills may be very vast. Competencies instead are more generic, and go beyond a specific job, they can be applied across all occupations and jobs. The number of competencies is therefore limited. *"Competencies determine whether or not people will acquire new job knowledge and skills, and how they will use that knowledge and skills to enhance their performance in the workplace."* (CEB Inc., 2016)

Table 4: The SHL Competency Framework
(Source: Own Representation Based on CEB Inc. (2016))

Competency Domain Title	Competency Dimension	Competency Component titles
1 Leading and Deciding	1.1Deciding & Initiating Action	1.1.1 Making Decisions 1.1.2 Taking Responsibility 1.1.3 Acting with Confidence 1.1.4 Acting on Own Initiative 1.1.5 Taking Action 1.1.6 Taking Calculated Risks
	1.2 Leading and Supervising	1.2.1 Providing Direction and Coordinating Action 1.2.2 Supervising and Monitoring Behavior 1.2.3 Coaching 1.2.4 Delegating 1.2.5 Empowering Staff 1.2.6 Motivating Others 1.2.7 Developing Staff 1.2.8 Identifying and Recruiting Talent
2 Supporting and Cooperating	2.1 Working with People	2.1.1 Understanding Others 2.1.2 Adapting to the Team 2.1.3 Building Team Spirit 2.1.4 Recognizing and Rewarding Contributions 2.1.5 Listening 2.1.6 Consulting Others 2.1.7 Communicating Proactively 2.1.8 Showing Tolerance and Consideration 2.1.9 Showing Empathy 2.1.10 Supporting Others 2.1.11 Caring for Others 2.1.12 Developing and Communicating Self-knowledge and Insight
	2.2 Adhering to Principles and Values	2.2.1 Upholding Ethics and Values 2.2.2 Acting with Integrity

		2.2.3 Utilizing Diversity 2.2.4 Showing Social and Environmental Responsibility
3 Interacting and Presenting	3.1 Relating & Networking	3.1.1 Building Rapport 3.1.2 Networking 3.1.3 Relating Across Levels 3.1.4 Managing Conflict 3.1.5 Using Humor
	3.2 Persuading and Influencing	3.2.1 Making an Impact 3.2.2 Shaping Conversations 3.2.3 Appealing to Emotions 3.2.4 Promoting Ideas 3.2.5 Negotiating 3.2.6 Gaining Agreement 3.2.7 Dealing with Political Issues
	3.3 Presenting and Communicating Information	3.3.1 Speaking Fluently 3.3.2 Explaining Concepts and Opinions 3.3.3 Articulating Key Points of an Argument 3.3.4 Presenting and Public Speaking 3.3.5 Projecting Credibility 3.3.6 Responding to an Audience
4 Analyzing and Interpreting	4.1 Writing and Reporting	4.1.1 Writing Correctly 4.1.2 Writing Clearly and Fluently 4.1.3 Writing in an Expressive and Engaging Style 4.1.4 Targeting Communication
	4.2 Applying Expertise and Technology	4.2.1 Applying Technical Expertise 4.2.2 Building Technical Expertise 4.2.3 Sharing Expertise 4.2.4 Using Technology Resources 4.2.5 Demonstrating Physical and Manual Skills 4.2.6 Demonstrating Cross Functional Awareness 4.2.7 Demonstrating Spatial Awareness
	4.3 Analyzing	4.3.1 Analyzing and Evaluating Information 4.3.2 Testing Assumptions and Investigating 4.3.3 Producing Solutions 4.3.4 Making Judgments 4.3.5 Demonstrating Systems Thinking
5 Creating and Conceptualizing	5.1 Learning and Researching	5.1.1 Learning Quickly 5.1.2 Gathering Information 5.1.3 Thinking Quickly 5.1.4 Encouraging and Supporting Organizational Learning 5.1.5 Managing Knowledge
	5.2 Creating and Innovating	5.2.1 Innovating 5.2.2 Seeking and Introducing Change
	5.3 Formulating Strategies and Concepts	5.3.1 Thinking Broadly 5.3.2 Approaching Work Strategically 5.3.3 Setting and Developing Strategy 5.3.4 Visioning
6 Organizing and Executing	6.1 Planning and Organizing	6.1.1 Setting Objectives 6.1.2 Planning 6.1.3 Managing Time 6.1.4 Managing Resources

		6.1.5 Monitoring Progress
	6.2 Delivering Results and Meeting Customer Expectations	6.2.1 Focusing on Customer Needs and Satisfaction 6.2.2 Setting High Standards for Quality 6.2.3 Monitoring and Maintaining Quality 6.2.4 Working Systematically 6.2.5 Maintaining Quality Processes 6.2.6 Maintaining Productivity Levels 6.2.7 Driving Projects to Results
	6.3 Following Instructions and Procedures	6.3.1 Following Directions 6.3.2 Following Procedures 6.3.3 Time Keeping and Attending 6.3.4 Demonstrating Commitment 6.3.5 Showing Awareness of Safety Issues 6.3.6 Complying with Legal Obligations
7 Adapting and Coping	7.1 Adapting and Responding to Change	7.1.1 Adapting 7.1.2 Accepting New Ideas 7.1.3 Adapting Interpersonal Style 7.1.4 Showing Cross-cultural Awareness 7.1.5 Dealing with Ambiguity
	7.2 Coping with Pressure and Setbacks	7.2.1 Coping with Pressure 7.2.2 Showing Emotional Self-control 7.2.3 Balancing Work and Personal Life 7.2.4 Maintaining a Positive Outlook 7.2.5 Handling Criticism
8 Enterprising and Performing	8.1 Achieving Personal Work Goals and Objectives	8.1.1 Achieving Objectives 8.1.2 Working Energetically and Enthusiastically 8.1.3 Pursuing Self-development 8.1.4 Demonstrating Ambition
	8.2 Entrepreneurial and Commercial Thinking	8.2.1 Monitoring Markets and Competitors 8.2.2 Identifying Business Opportunities 8.2.3 Demonstrating Financial Awareness 8.2.4 Controlling Costs 8.2.5 Keeping Aware of Organizational Issues

3.3.2 Advantages of the SHL Competency Framework

The SHL Competency Framework has been developed based on competency approaches from practice. Most competency frameworks or dictionaries are based and developed on content analysis while the SHL Competency Framework is based on a more structured, evidence-based approach (Bartram, 2005). In this way it delivers competencies that have been proved in the practice to be needed and necessary to describe certain jobs.

"Choosing this existing framework offers many advantages. It offers a state of the art structure for competency modeling by not only listing the competencies but also showing the relationships between them. The framework is used both in research and practice, so our work makes a two-fold contribution. Since many companies apply it to build their competency profile, it offers the potential to compare our results with industry profiles in practice.
The SHL UCF developed by CEB Inc. is based on different competency approaches from research and practice (Bartram, 2005). It offers a behavioral approach for competency modeling

by focusing on the individual and considering competencies of behavioral nature, meaning an individual can learn and adopt them unlike, e.g., personality. As a framework it offers a structure and overview of the competencies, by fitting them into descriptive categories (Frankfort-Nachmias, Nachmias, & Dewaard, 2014). This framework can be used to develop competency models, which represent a descriptive and simplified view of the competencies as a specific phenomenon to be analyzed (Frankfort-Nachmias et al., 2014). The SHL UCF is widely used in practice and many companies use it to describe their competency models for specific job positions (Kleindauer et al., 2012). “ (Prifti, Knigge, Kienegger, et al., 2017)

3.3.3 Model Development

A total of 64 competencies were discovered in the literature. Further the four focus group discussions that were transcribed and analyzed were available. From the focus groups analysis a total of 53 competencies were extracted. 49 of these competencies were already mentioned in the literature, which evaluated these results, while additional competencies could be added to the list, by expanding it to a total number of 69 competencies. 16 of the competencies that were mentioned in the literature did not come up in the focus group discussions. However these competencies were included in the final results, since they are important competencies that due to the nature of the discussion did not come up, the reasons for this are also described in Section 3.7 The Context of the Competencies.

At this point a total of 69 competencies considered relevant for Industry 4.0 were identified. Based on the results of the literature and focus groups some of the single competencies were adapted in their formulation to better serve the purpose of this theses.

By using the SHL Competency Framework the 69 competencies were classified and put in the frame of the delivered framework, by keeping its structure and the delivered relationships between the competencies. While for some competencies e.g. Leadership Skills, Entrepreneurship etc., it was straight forward, how they could be classified, since they are directly presented in the framework under the same term, for other competencies it was not directly clear how they could be classified. These were mainly competencies that described a domain related competencies like: Cloud Computing, Predictive Maintenance etc. Therefore as a first step the author of the thesis did a classification on her own and put the competencies in the frames delivered by SHL based on the relevance that could be extracted for each of them, their description, and the context how they were mentioned in the literature as well as the focus group discussions. However in order to have a clear and not biased classification, the same process was conducted as a second step, independently from a research assistant. The results were compared and discussed in case of any disagreement until a final decision could be reached. The categorization of most of the competencies was straight forward, since they are of a behavioral nature and fell directly under a predefined category in the framework. In case of competencies that describe knowledge about a certain area as Cloud Computing or Predictive Maintenance, after discussing it, it was decided that these competencies should be classified under the area of Big Eight competency of Analyzing and Interpreting, in the dimension Applying Expertise and Technology. The reason is that all these kind of competencies are of a technical nature and describe the ability to apply a certain technology or expertise in a certain area.

At the end the structure and the relationship between the elements of the SHL Framework was kept and the third level competencies were adapted based on the results of this research. The framework delivers 112 single competencies, however in the presented model 69 competencies, are considered relevant for Industry 4.0.

As mentioned the focus in this thesis lies in defining competencies for IS/CS and Engineering. Therefore it was also important to define for which areas each of these competencies are relevant. For each of the defined and classified competencies in the model, a further categorization, if it is relevant for IS, CS and Engineering was conducted. This step was conducted again in parallel and independently from the author of the thesis as well as a research assistant. In case of a disagreement it was discussed until achieving a consensus. However the most competencies are relevant for all three areas, regardless if it is IS, CS or Engineering. Since they are competencies of a behavioral nature. The only area where there is a difference between the competencies is the area of the competency dimension Applying Expertise and Technology. In this dimension there is a differentiation between the competencies for the three areas of specialization, since the competencies in this dimension describe technology ability, which is different, depending on the specialization of the employees.

3.4 Results of Literature

Based on the literature, a total of 64 competencies could be derived (Figure 10). They were mostly of a behavioral nature by underlining the importance of behavioral competencies for Industry 4.0. Communicating with people is one of the key competencies required from academics as mentioned by many authors (acatech et al., 2016; Erol et al., 2016; Gehrke et al., 2015; Grega & Kornecki, 2015; Grimheden & Törgren, 2014; Gudanowska, 2017; Guo, 2015; Kagermann et al., 2013; Kiesel & Wolpers, 2015; Klinkel, Rahn, & Bernhard, 2017; Kusmin,

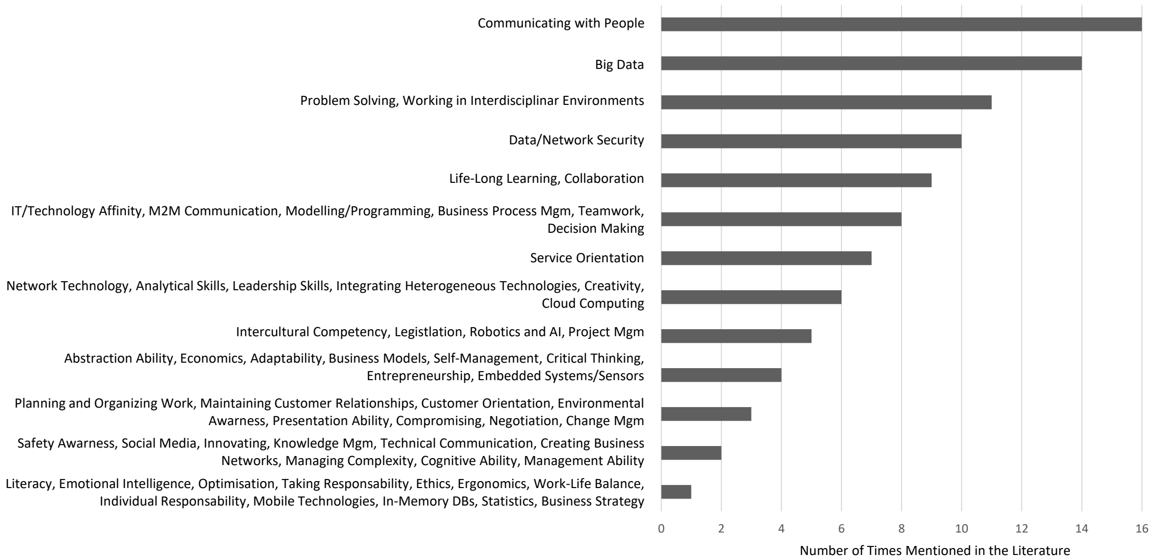

Figure 10: Competencies Mentioned in the Literature
Source: Own Representation

Ley, & Normak, 2018; Maenpaa, Tarkoma, Varjonen, & Vihavainen, 2015; Richter et al., 2015; Mäkiö-Marusik, Ahmad, Harrison, Mäkiö, & Colombo, 2018; Smit et al., 2016; Xia, 2011).

Other authors go further by putting the communication competency in relation with other competencies like literacy (Xia, 2011) and technical communication (Erol et al., 2016; Xia, 2011), intercultural competency (Erol et al., 2016; Gudanowska, 2017; Guo, 2015; Kusmin, et al., 2018; Xia, 2011) or presentation ability (Blanchet, Rinn, von Thaden, & de Thieulloy, 2014; Gudanowska, 2017; Mäkiö-Marusik, 2017). Social skills like cooperating with others (acatech et al., 2016; Blanchet et al., 2014; Gray, 2016; Gudanowska, 2017; Kiesel & Wolpers, 2015; Klinkel, et al., 2017; Kusmin, et al., 2018; Mäkiö-Marusik, et al., 2018; Richter et al., 2015), compromising (Erol et al., 2016; Gudanowska, 2017; Kusmin, et al., 2018) and negotiating (Gray, 2016; Gudanowska, 2017; Vaidya, Ambad, & Bhosle, 2018) combined with emotional intelligence (Gray, 2016) will play a key role in Industry 4.0 since they also play an important aspect in teamwork (Erol et al., 2016; Gehrke et al., 2015; Grega & Kornecki, 2015; Gudanowska, 2017; Kiesel & Wolpers, 2015; Klinkel, et al., 2017; Kusmin, et al., 2018; Richter et al., 2015), project management (Grimheden & Törgren, 2014; Gudanowska, 2017; Maenpaa et al., 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018) and management ability (Gudanowska, 2017; Smit et al., 2016), customer orientation (acatech et al., 2016; Guo, 2015; Klinkel, et al., 2017), maintaining customer relationships (acatech et al., 2016; Hoberg et al., 2015; Klinkel, et al., 2017) and creating business networks (acatech et al., 2016; Hoberg et al., 2015; Klinkel, et al., 2017; Müller, et al., 2018).

Work and cooperation will become more complex, therefore Industry 4.0 will require academics with analyzing competencies like problem solving (acatech et al., 2016; Erol et al., 2016; Gebhardt et al., 2015; Gray, 2016; Gudanowska, 2017; Kiesel & Wolpers, 2015; Klinkel, et al., 2017; Mäkiö-Marusik, 2017 ; Richter et al., 2015; Smit et al., 2016; Windelband, 2014), optimization (acatech et al., 2016; Gebhardt et al., 2015), analytical skills (Erol et al., 2016; Hartmann & Bovenschulte, 2013; Kusmin, et al., 2018; Lorenz, Rüßmann, Strack, Lueth, & Bolle, 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018) and cognitive ability (Gray, 2016; Gudanowska, 2017). To be able to coordinate this competencies and succeed the competency of managing complexity (acatech et al., 2016; Erol et al., 2016) and abstraction ability (Erol et al., 2016; Gudanowska, 2017; Smit et al., 2016; Windelband, 2014) will play a crucial role. Academics in Industry 4.0 should bring leading and deciding competencies like decision making (acatech et al., 2016; Gray, 2016; Gudanowska, 2017; Kagermann et al., 2013; Kortuem, Bandara, Smith, Richards, & Petre, 2013; Kusmin, et al., 2018; Smit et al., 2016; Vaidya, et al., 2018), taking responsibility (Smit et al., 2016) and leadership skills (acatech et al., 2016; Gray, 2016; Gudanowska, 2017; Kusmin, et al., 2018; Lorenz et al., 2015; Smit et al., 2016), which should be combined with a set of principles and values with competencies as respecting ethics (Grega & Kornecki, 2015), environmental awareness (Grimheden & Törgren, 2014; Maenpaa et al., 2015; Müller, et al., 2018) and awareness for ergonomics (Gehrke et al., 2015).

Industry 4.0 will bring a dynamic, international and interdisciplinary work environment, therefore competencies as working in interdisciplinary environments (acatech et al., 2016; Ansari, et al., 2018; Blanchet et al., 2014; Gebhardt et al., 2015; Gehrke et al., 2015; Grega & Kornecki, 2015; Klinkel, et al., 2017; Lorenz et al., 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018; Richter et al., 2015), flexibility (Erol et al., 2016; Gudanowska, 2017; Klinkel, et al., 2017; Kusmin, et al., 2018; Mäkiö-Marusik, 2017), adaptability (Gehrke et al., 2015; Kiesel & Wolpers, 2015; Gudanowska, 2017; Klinkel, et al., 2017) as well as innovating (acatech et al., 2016; Stocker et al., 2014), creativity (Erol et al., 2016; Kiesel & Wolpers, 2015; Kusmin, et al., 2018; Mäkiö-Marusik, 2017; Richter et al., 2015; Stocker et al., 2014), critical thinking (Gudanowska, 2017; Kiesel & Wolpers, 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018), and change management (Hoberg et al., 2015; Hovanski, et al., 2017; Gudanowska, 2017) gain a new importance. To be able to always adapt to the newest technologies and make the most out of them, academics should apply life-long learning (Blanchet et al., 2014; Erol et al., 2016; Gebhardt et al., 2015; Gehrke et al., 2015; Grega & Kornecki, 2015; Kiesel & Wolpers, 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018; Lorenz et al., 2015) and knowledge management (Gehrke et al., 2015; Kiesel & Wolpers, 2015) while being focused on business strategy (Zinn, 2015), always changing business models (Blanchet et al., 2014; Zinn, 2015) and entrepreneurship (Gudanowska, 2017; Kiesel & Wolpers, 2015; Klinkel, et al., 2017; Kusmin, et al., 2018; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018). The work environment will become very demanding so an academic will need to find work-life balance (Erol et al., 2016) and have the competency of self-management and organization (Gehrke et al., 2015; Kagermann et al., 2013; Kiesel & Wolpers, 2015; Smit et al., 2016) and of planning and organizing work (Guo, 2015; Hartmann & Bovenschulte, 2013; Kiesel & Wolpers, 2015). Nevertheless he should bring legislation (Gehrke et al., 2015; Grimheden & Törgren, 2014; Maenpaa et al., 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018) and safety awareness (Grega & Kornecki, 2015; Hartmann & Bovenschulte, 2013) as well as individual responsibility (Smit et al., 2016).

Apart from all the behavioral competencies mentioned above academic must also bring domain related competencies and the ability to apply expertise and use technology. In this aspect all academics must bring IT and technology affinity (acatech et al., 2016; Erol et al., 2016; Gebhardt et al., 2015; Gehrke et al., 2015; Guo, 2015; Hartmann & Bovenschulte, 2013; Hoberg et al., 2015; Lorenz et al., 2015), economics knowledge (Grimheden & Törgren, 2014; Maenpaa et al., 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018) and be able to use social media to achieve a value for the company (Erol et al., 2016; Hoberg et al., 2015). IS graduates should have knowledge in service orientation and product service offerings (acatech et al., 2016; Chunzhi, Hui, & Xia, 2012; Hoberg et al., 2015; Gudanowska, 2017; Klinkel, et al., 2017; Mabkhot, et al., 2018; Zinn, 2015), business process (acatech et al., 2016; Blanchet et al., 2014; Erol et al., 2016; Hovanski, et al., 2017; Gehrke et al., 2015; ; Gudanowska, 2017; Kusmin, et al., 2018; Zinn, 2015) and change management (Hoberg et al., 2015). IT/computer science professionals should have knowledge of digital security, including data and network (acatech et al., 2016; Chunzhi et al., 2012; Grega & Kornecki, 2015; Gudanowska, 2017; Hoberg et al., 2015; Kusmin, et al., 2018; Mäkiö-Marusik, et al., 2018; Vaidya, et al., 2018; Veile, et al., 2018; Zinn, 2015), and while working with engineers both groups should bring the competency of integrating heterogeneous technologies (Grega & Kornecki, 2015; Grimheden & Törgren, 2014; Klinkel, et al., 2017; Maenpaa et al., 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018), knowledge about mobile technologies (Hoberg et al., 2015) and embedded systems and sensors (Grega & Kornecki, 2015; Koska, et al., 2017; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018), knowing network technology and M2M communication (acatech et al., 2016; Blanchet et al., 2014; Chunzhi et al., 2012; Erol et al., 2016; Gebhardt et al., 2015; Klinkel, et al., 2017; Koska, et al., 2017; Zinn, 2015) as well as possess knowledge of robotics and artificial intelligence (acatech et al., 2016; Ansari, et al., 2018; Hartmann & Bovenschulte, 2013; Klinkel, et al., 2017; Lorenz et al., 2015). On the other hand, IT/computer science and IS/economics professionals should both bring modelling and programming knowledge (Chin & Callaghan, 2013; Erol et al., 2016; Gehrke et al., 2015; Klinkel, et al., 2017; Kortuem et al., 2013; Kusmin, et al., 2018; Lorenz et al., 2015; Mäkiö-Marusik, 2017), knowledge about cloud computing and cloud architectures (acatech et al., 2016; Chunzhi et al., 2012; Hoberg et al., 2015; Koska, et al., 2017; Mabkhot, et al., 2018; Müller, et al., 2018; Sreedharan, & Unnikrishnan, 2017; Vaidya, et al., 2018), in-memory DB knowledge (Hoberg et al., 2015) and statistics (Gehrke et al., 2015). For both groups, big data and data analysis and interpretation (acatech et al., 2016; Bechtold, Lauenstein, Kern, & Bernhofer, 2015; Blanchet et al., 2014; Erol et al., 2016; Gehrke et al., 2015; Hoberg et al., 2015; Kaiser, et al., 2018; Klinkel, et al., 2017; Lorenz et al., 2015; Mabkhot, et al., 2018; Müller, et al., 2018; Vaidya, et al., 2018; Sreedharan, & Unnikrishnan, 2017; Zinn, 2015) will be of big importance.

3.5 Results of Focus Groups

Others than in the literature, where communication was the top mentioned competency, the most mentioned competency in the focus groups was big data/data analytics competency. "*I think it is about all different kind of data, also geo data but also video data, images, all ERP data, structured data and unstructured data like Facebook etc.„ "So to use anonymized big data and volume data and data traffic to predict macro business events rather than micro.„; "You need to understand how the data is gathered before you can actually start and appreciate. „ "In the Internet of Things I think that prediction is important. We should analyze data to know when something is going to happen." „I think text mining is important and can be used in many scenarios„ "How can the data be used to get information from the machine? To figure out when is the right window to do the maintenance. „ " Yes to analyze the data. And figure out when are the best windows for maintenance. So you can just minimize the set down of your high productive assets. „*

The participants of the focus groups recognize the importance of big data for the Industry 4.0. In deed in a connected world it will gain a big importance. A combination of big data competency with sensors and mobile technology as well as predictive maintenance and machine learning will be very important to use the full potential of Industry 4.0.

Knowledge about sensors was also widely mentioned in the focus groups. Sensors are one of the main components making Industry 4.0 possible, as also mentioned by (Kagermann et al., 2013). In the focus groups, many participants mentioned sensor know how as important and a competency that should be taught to people who will work in Industry 4.0. *"I really would have … some classification or some overview over all the sensors when we talk about Industry 4.0 or Internet of Things. „ "…sensors … do not cost so much and are easy to bind them into data system. „ "You need to understand how the data is gathered before you can actually start and appreciate." "I may have sensors that may help to have less interruption in the production. „*

The participants also mention mobile technology by focusing on its important especially regarding apps development. *"I think it would be exiting to learn to develop apps for different purposes.„*

As a combination of the three mentioned technologies predictive maintenance is possible. Through sensors data is generated that overviews the machines. Through mobile technologies, it can be transmitted and made available for analysis and through data analytics the data can be analyzed and possible future errors can be predicted. The mentioned technologies create a basis for Industry 4.0 which is also a basis for predictive maintenance. *"In the production company which has a huge amount of assets there might be interesting to monitor utilization of machines. So if I have a proactive maintenance aspect, we would have just a minimum set down due to proactive maintenance and a high utilization of machines as part of Industry 4.0. „;* "…get this kind of information from the machine. Figure out when is the right window to do the maintenance. *„; "A big problem for chemical pharma company or automotive company is that the machines cost millions of dollars that they work 100% of the time. And if it breaks down, unexpected, then you have a huge amount of loss and couple of days where they stays. But you can do proactive maintenance. „*

Process know-how and process management competency were also widely mentioned from the focus groups participants. Processes and process automation play a crucial role in Industry 4.0. *"Knowledge about new processes perhaps…„*

The participants also mention the importance of business model understanding, entrepreneurship and servitization. All these competencies are crucial for Industry 4.0. Through the new technologies and possibilities many new business models will arise. In this context servitization plays and important role, since many companies are transforming from producing companies to product service offering companies. Being able to cope with new business models and services requires also entrepreneurship competency. *"We are looking for students start working in a company and can make new combinations to position themselves best on the market, innovative ideas, just showing them these ideas and breaking it down so they can build different combinations. „ "Maybe the students can look how the processes change and what business models arise from that."* The employees of tomorrow should be prepared to use the technological advances as an advantage and adapt in a fast changing world. "*The question is: Which potential does the digitalization bring and which new services can be offered based on that? „*

The participants also stressed that interdisciplinary competency will play a new role in Industry 4.0. An engineer will have to collaborate with the IS and CS specialists in order to achieve results in the interconnected environment that we will face. *"I think that the interfaces with other disciplines are very interesting. „*

The domain or analytical oriented competencies like IT and technology affinity, network administration, data security cloud architectures, programming, in-memory DBs were also important in the discussion. *"Just to have the picture. You run through the world and Industry 4.0, you know there are so much sensors. „ "The more technical people they should know afterwards how to create systems. „; "We need people who can program a little" "Security is becoming much more important than in our classical systems„*

In the discussion the participants also mentioned various behavioral competencies like customer orientation, decision making, communication, innovating, legal, ethics, and teamwork. *"I do not need to understand the whole technical background, but I need to be able to make decisions. „; "…we should offer group work, so that the participants learn to communicate and w*ork in te*ams"; ".. to think what are my possibilities and what is my goal like critical thinking„*

In comparison to the literature four new competencies that were mentioned in the focus groups but have not been found in literature, as customer relationship management, IT architectures, predictive maintenance and machine learning could be added. Some of the competencies that were often mentioned and discussed in the literature have not been mentioned at all during the focus groups. The mentioned competencies were generally more abstract, lacking high detail compared to the literature. The reason for this lies in the nature of the discussion. Why in the literature, the authors have applied research methods, and detailed their results, in the focus groups, the participants had to generate ideas on the fly. Therefore the results of the focus groups are more generic.

3.6 The Competency Model

The delivered model describes a total of 69 competencies that can be put in relationship to one another to 20 competency dimensions and further on can be grouped in eight big competencies

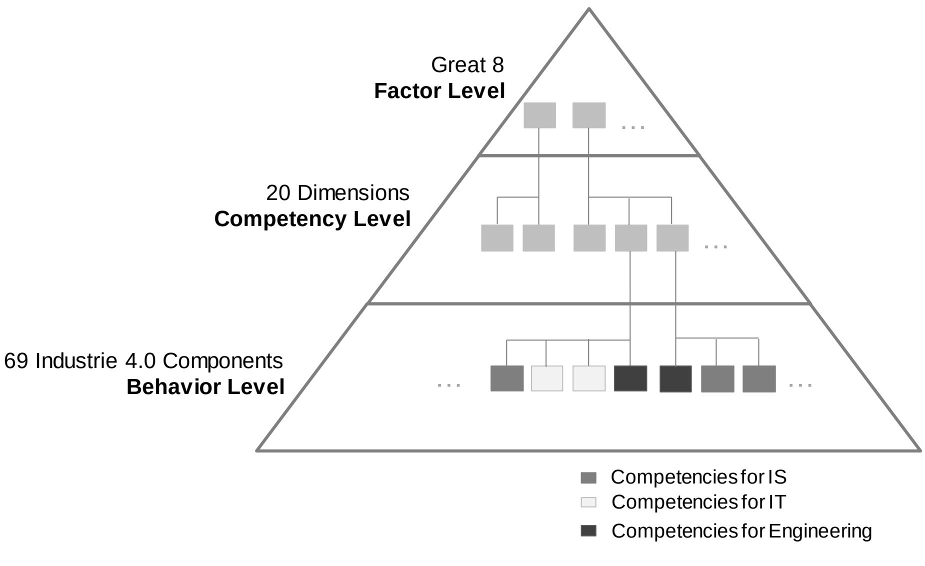

Figure 11: Structure of Competency Model
(Source: Own Representation Based on Iliescu (2012))

as described in the SHL competency framework. The structure of the competency framework is described in Figure 11.

<table>
<tr><th>Big Eight</th><th>Competency Dimensions</th><th colspan="3">Competencies</th></tr>
<tr><th></th><th></th><th>Information Systems (IS)</th><th>Computer Science</th><th>Engineering</th></tr>
<tr><td rowspan="2">Leading & Deciding</td><td>Deciding and Initiating Action</td><td colspan="3">• Decision Making
• Taking Responsibility</td></tr>
<tr><td>Leading and Supervising</td><td colspan="3">• Leadership Skills</td></tr>
<tr><td rowspan="2">Supporting and Cooperating</td><td>Working with People</td><td colspan="3">• Teamwork
• Collaborating with Others
• Communicating with People</td></tr>
<tr><td>Adhering to Principles and Values</td><td colspan="3">• Respecting Ethics
• Environmental Awareness
• Awareness for Ergonomics</td></tr>
<tr><td rowspan="3">Interacting and Presenting</td><td>Relating and Networking</td><td colspan="3">• Compromising
• Creating Business Networks
• Maintaining Customer Relationships</td></tr>
<tr><td>Persuading and Influencing</td><td colspan="3">• Negotiating
• Emotional Intelligence</td></tr>
<tr><td>Presenting and Communicating Information</td><td colspan="3">• Presentation and Communication Ability</td></tr>
<tr><td rowspan="6">Analyzing and Interpreting</td><td>Writing and Reporting</td><td colspan="3">• Targeted/Technical Communication
• Literacy</td></tr>
<tr><td rowspan="4">Applying Expertise and Technology</td><td colspan="3">• IT and Technology Affinity
• Economics
• Extract Business Value from Social Media</td></tr>
<tr><td>• Service Orientation/ Product Service Offerings
• Business Process Management
• Business Change Management
• Understand and Coordinate Workflows</td><td>• Network Security
• IT Architectures
• Machine Learning</td><td></td></tr>
<tr><td></td><td colspan="2">• System Development
• Integrating Heterogeneous Technologies
• Mobile Technologies
• Sensors/Embedded Systems
• Network Technology /M2M Communication
• Robotics/Artificial Intelligence
• Predictive Maintenance</td></tr>
<tr><td colspan="2">• Modelling and Programming
• Big Data/Data Analysis and Interpretation
• Cloud Computing /Architectures
• In-Memory DBs
• Statistics
• Data Security</td><td></td></tr>
<tr><td>Analyzing</td><td colspan="3">• Problem Solving
• Optimization
• Analytical Skills
• Cognitive Ability</td></tr>
<tr><td rowspan="3">Creating and Conceptualizing</td><td>Learning and Researching</td><td colspan="3">• Life-long Learning
• Knowledge Management</td></tr>
<tr><td>Creating and Innovating</td><td colspan="3">• Innovating
• Creativity
• Critical Thinking
• Change Management</td></tr>
<tr><td>Formulating Strategies and Concepts</td><td colspan="3">• Business Strategy
• Abstraction Ability
• Managing Complexity</td></tr>
<tr><td rowspan="3">Organizing and Executing</td><td>Planning and Organizing</td><td colspan="3">• Project Management
• Planning and Organizing Work
• Management Ability</td></tr>
<tr><td>Delivering Results and Meeting Customer Expectations</td><td colspan="3">• Customer Orientation
• Customer Relationship Management</td></tr>
<tr><td>Following Instructions and Procedures</td><td colspan="3">• Legislation Awareness
• Safety Awareness
• Individual Responsibility</td></tr>
</table>

Big Eight	*Competency Dimensions*	*Competencies*		
		IS/Economics	IT/Computer Science	Engineering
Adapting and Coping	*Adapting and Responding to Change*	• Work in Interdisciplinary Environments • Intercultural Competency • Flexibility • Adaptability and Ability to Change Mind-set		
	Persuading and Influencing	• Work-Life Balance		
Enterprising and Performing	*Achieving Personal Work Goals and Objectives*	• Self-management and -organization		
	Entrepreneurial and Commercial Thinking	• Business Model Understanding • Entrepreneurship		

Figure 12: Competency Model for Industry 4.0
(Source: Prifti, Knigge, Kienegger, and Krcmar (2017))

The model itself is presented in Figure 12. "The results show that most of the behavioral competencies should be adapted by all three groups of graduates. These competencies are marked in light grey color e.g. *Decision Making* or *Teamwork*. It means that the employees of the future, independently from their position should bring a high level of behavioral competencies to successfully work in Industry 4.0. Only competencies under the dimension "Applying Expertize and Technology" have three variants. This dimension of competencies represents domain knowledge, therefore depending on the domain the employees should bring different competencies. Some competencies in this dimension are also categorized to two or more groups of graduates. E.g., *Predictive Maintenance* will be a competency for IT as well as for Engineering graduates, whereas *Big Data* will be a needed competency not only for IS but also for IT graduates. Economics graduates, who follow a technical oriented career path, will adapt similar competencies as the IS graduates, since these disciplines have similarities. This shows again that the work in Industry 4.0 will be interconnected. Therefore, competencies such as interdisciplinary working, collaboration, communication or teamwork will have a special role.

For each of the employee groups you can follow the path and gather all the competencies that should be fulfilled by this group. It cannot be expected that one employee of a certain group masters all the competencies. Therefore, a combination of the competencies, depending on the position will deliver different job profiles for Industry 4.0. E.g. a competency profile for a data scientist *Responsibility*, *Big Data Analytics and Interpretation*, *Analytical Skills*, *Cognitive Ability*, *Creativity*, and *Critical Thinking*. By following this schema different profiles for different jobs responsible for extracting, modeling and visualizing the data produced by a certain sensor in Industry 4.0 can be defined by extracting concrete competencies from the area of IS such as *Taking* could be defined*." (Prifti, Knigge, Kienegger, et al., 2017)*

3.7 The Context of the Competencies

In the chapter above the method as well as the competency model that was delivered during the answering of this research question were described. In this chapter the single competencies are listed, by describing and discussing their relevance and the area of work in which they will be relevant in Industry 4.0. For each competency it is also defined rather it is relevant for IS, CS or Engineering. How this classification was made is described in 3.3 Developing the Model.

1. Deciding and Initiating Action

1.1 Deciding and Initiating Action

Decision Making (IS/CS/Eng): Decision making ability includes the ability to weight possible alternatives regarding their advantages and disadvantages and be able to commit to one of them. To achieve it, an employee should be able to forecast possible outcomes that may come as a result of a certain alternative. In Industry 4.0 where the automation of the work processes is high, and many technologies are available the work environment is changing, therefore the employees should be able to make fast decisions under stress situations. For this reason various authors agree that academics in Industry 4.0 should bring decision making competencies (acatech et al., 2016; Gray, 201(acatech et al., 2016; Gray, 2016; Gudanowska, 2017; Kagermann et al., 2013; Kortuem, Bandara, Smith, Richards, & Petre, 2013; Kusmin, et al., 2018; Smit et al., 2016; Vaidya, et al., 2018)6; Kagermann et al., 2013; Kortuem et al., 2013; Smit et al., 2016) as it is very important for the work in the future. The same situation is presented in the focus groups where the participants recognize the importance of decision making competency in an Industry 4.0 work environment. *"I do not need to understand the whole technical background, but I need to be able to make decisions."* This competency should be present in all three areas including IS, CS and Engineering. Depending on the exact job position it is more important for persons in leading and managing roles.

Taking Responsibility (IS/CS/Eng): Taking responsibility means being able to follow the duties on the job, and be accountable for situations that might occur. It is important for all three areas of the competency model including IS, CS and Engineering. It is strongly connected with Decision Making competency since taking responsibility means also being able to make decisions in certain situations. As it was mentioned in the focus groups: *"I do not need to understand the whole technical background, but I need to be able to make decisions."* Smit et al. (2016) mention in the literature that taking responsibility is important in Industry 4.0: "a socio-technical approach to work organization will offer workers the opportunity to enjoy greater responsibility"

1.2 Leading and Supervising

Leadership Skills (IS/CS/Eng): Leadership skill is described as the ability to lead a group or an organization by establishing a clear vision and providing methods, tools, information and knowledge to fulfil it. It is strongly connected with Decision Making and Taking Responsibility, however it goes a step further, since it requires in leading to a greater goal, while decision making and responsibility taking may be connected to a single event. Leadership skills are very important in Industry 4.0 in order to reach the greater vision of automation. Therefore it is needed in all three areas analyzed in this thesis. However this skill is only needed for a certain group of people in leading roles in each of the areas and not from everyone. As Smit et al.

(2016) summarizes: "individual responsibility, decentralized leadership, and management approaches to allow greater freedom in decision-making". The participants of the focus groups also suggested a similar combination of this responsibilities: *"I do not need to understand the whole technical background, but I need to be able to make decisions."* Many authors e.g. (acatech et al., 2016; Gray, 2016; Gudanowska, 2017; Kusmin, et al., 2018; Lorenz et al., 2015; Smit et al., 2016) mention leadership skills as crucial for Industry 4.0.

2. Supporting and Cooperating

2.1 Working with People

Teamwork (IS/CS/Eng): Teamwork describes the ability to work together with other people in order to achieve a certain goal. It is important in Industry 4.0, since projects will become more complex, so that the tasks will be shared between different people. It means that people should be able to communicate, collaborate and work together despite personal preferences. Teamwork competency is necessary for every employee in Industry 4.0 regardless if their area is IS, CS or Engineering and regardless of their concrete position or hierarchy in the job. Teamwork competency is often mentioned in the literature (Erol et al., 2016; Gehrke et al., 2015; Grega & Kornecki, 2015; Gudanowska, 2017; Kiesel & Wolpers, 2015; Klinkel, et al., 2017; Kusmin, et al., 2018; Richter et al., 2015). Grega and Kornecki (2015) mention the "..ability to assume a variety of roles in teams of diverse membership" as an important factor. The results in the focus groups were similar: "*we should offer group work, so that the participants learn to communicate and w*ork in teams".

Collaborating with Others (IS/CS/Eng): Collaboration is the ability to interface successfully with others on the job. To be able to cooperate is important to have the right team spirit for teamwork and communication ability in order to combine the personal interests with the group goals. Similar to teamwork this competency is necessary for every employee in Industry 4.0 regardless if their area is IS, CS or Engineering and regardless of their concrete position or hierarchy in the job. The literature mentions the competency of collaborating with others as important in Industry 4.0 (acatech et al., 2016; Blanchet et al., 2014; Gray, 2016; Gudanowska, 2017; Kiesel & Wolpers, 2015; Klinkel, et al., 2017; Kusmin, et al., 2018; Mäkiö-Marusik, et al., 2018; Richter et al., 2015). In an environment where work is more complex, being able to synchronize and collaborate with others is crucial. Similar results were presented also in the focus groups, where participants mentioned the ability to collaborate as important for Industry 4.0. *"... learn to work with others.."*

Communicating with People (IS/CS/Eng): Communication is the ability to transmit information to other people in an effective and efficient way. A good communication ability helps to share information and be understood with others. In an Industry 4.0 environment, where the employees will be faced with challenges that they should be able to solve together, communication competency is a key ability. This ability is necessary for every employee from IS, CS and Engineering. In fact the literature mentions communication as the most important competency for Industry 4.0 (acatech et al., 2016; Erol et al., 2016; Gehrke et al., 2015; Grega & Kornecki, 2015; Grimheden & Törgren, 2014; Gudanowska, 2017; Guo, 2015; Kagermann et al., 2013;

Kiesel & Wolpers, 2015; Klinkel, Rahn, & Bernhard, 2017; Kusmin, Ley, & Normak, 2018; Maenpaa, Tarkoma, Varjonen, & Vihavainen, 2015; Richter et al., 2015; Mäkiö-Marusik, Ahmad, Harrison, Mäkiö, & Colombo, 2018; Smit et al., 2016; Xia, 2011). "On an employee level, Industry 4.0 propagates the idea of workers that increasingly will focus on creative, innovative and communicative activities." (Erol et al., 2016) "Employees will be expected to … have excellent communication skills." (Smit et al., 2016). Apart from the literature, also in the focus groups, communication competency was mentioned as an important competency for Industry 4.0 *"... so that the participants learn to communicate ..."*.

<u>2.2 Adhering to Principles and Values</u>

Respecting Ethics (IS/CS/Eng): Ethics include a set of moral principles, regarding what is good and right and what not, that is accepted and followed by the society. In a world where automation, sensors, privacy etc., play a big role, ethics win a new importance since a whole set of principles are redefined. In Industry 4.0 where the technological advances are big, it helps in using technology with responsibility without endangering human personality or privacy. Therefore people who work in Industry 4.0 and cope with these technologies should bring a set of moral values with them and respect ethics in the context of Industry 4.0. This competency is important for all three areas and every role. As Grega and Kornecki (2015) mentions „…understanding of the professional and ethical responsibilities of the design of life- and safety-critical systems…" Also in the focus groups the participants mentioned the importance of ethical competency *"... for example when social networks are analyzed .... we want to gain information, without losing any part of it, but we should be careful so that you cannot find out who was the person that posted it…"*.

Environmental Awareness (IS/CS/Eng): Environmental awareness means in being able to understand the fragility of the environment and the importance to protect it. In Industry 4.0 where technology evolves and plays an even bigger role it is important to understand the impact that it may have on the environment and plan carefully the steps of technology in order for them to be synchronized with, and respect the environment. Therefore Industry 4.0 employees should bring environmental awareness regardless of the area where they work or their exact role in the company. In the literature (Grimheden & Törgren, 2014; Maenpaa et al., 2015; Müller, et al., 2018) environmental awareness is mentioned as an important competency in Industry 4.0. Maenpaa et al. (2015) mention that employees should bring "life-cycle concern including environmental effects". This competency was however not mentioned during the focus groups. The reason for that could be that in today's world it is considered as a must have competency for each citizen in every area. Therefore the participants of the focus groups did not mention this competency as specific for Industry 4.0.

Awareness for Ergonomics (IS/CS/Eng): Ergonomics includes the process of designing and arranging workplaces, products and systems so that they fit to the people who use them. In Industry 4.0 it is important to design systems that are fitted and adapted to the people. First of all people will have to work a lot more with machines, so these should be design with regards to ergonomic principles. Second, due to less physical activity, people nowadays often suffer under health issues, therefore designing ergonomic systems would help in improving the health. It is important that people who work in Industry 4.0 bring an awareness for ergonomics and respect the principles of ergonomics in designing machines and work places for themselves and others. This competency is relevant for all three areas discussed in this thesis as well as for every role in the company. Gehrke et al. (2015) mention awareness for ergonomics as a competency for Industry 4.0. However this competency, similar to the environmental awareness was not mentioned in the focus groups. Maybe because it is considered very special, and although it is important to protect oneself and others is still not in the focus of the work environment.

3. Interacting and Presenting

3.1 Relating and Networking

Compromising (IS/CS/Eng): Compromising is the ability to find an intermediate way between two alternatives in case of a conflict. In this case, both parties should concede parts of their requests. In Industry 4.0 where many decisions are taken, it is often important to be able to compromise and concede certain requests and needs by finding an intermediate way that may also make the other party happy (Erol et al., 2016; Gudanowska, 2017; Kusmin, et al., 2018). This competency has a relevance for all the areas of work in Industry 4.0. Erol et al. (2016) mention the importance of consensus finding ability and compromising. This competency was however not directly mentioned in the focus groups. The participants mentioned communication ability and teamwork as important competencies, and they imply at some point also compromising ability.

Creating Business Networks (IS/CS/Eng): Business networking is the process of establishing a mutually beneficial relationship with other business people and potential clients and/or customers. The primary purpose of business networking is to tell others about your business and hopefully turn them into partners or customers. In Industry 4.0 every company is specialized, therefore cooperation between companies is crucial for businesses. Employees in Industry 4.0 should bring the ability of business networking in order to create new partnership and also gain new customers in the context of Industry 4.0. This competency should be present in all three areas IS, CS and Engineering. However it is of higher relevance for managerial and leading roles, or special roles who are in contact with people outside the organization. The competency of creating business networks is mentioned mainly from the practitioners literature (acatech et al., 2016; Hoberg et al., 2015; Klinkel, et al., 2017; Müller, et al., 2018). In the focus groups it was mainly mentioned in the context of maintaining customer relationships: *"... understand what the customer wants…".*

Maintaining Customer Relationships (IS/CS/Eng): The competency of maintaining customer relationships is strongly connected to the ability of business networking, however in this case it is directly focused on the customers. Since customers are an important resource for a business, it is important for employees in Industry 4.0 to be able to maintain the relationships with the customers. Both in the scientific and practitioner literature (acatech et al., 2016; Hoberg et al., 2015; Klinkel, et al., 2017) this competency was mentioned as important for Industry 4.0. Also in the focus groups the participants recognize the importance of this competency and mention its relevance: *"... understand what the customer wants…", "…analyze how the customers* *buy…”.* Similar to creating business networks this competency should be present in all three analyzed areas, namely IS; CS and Engineering. However it is more relevant for special roles in the company who has contact to customers.

3.2 Persuading and Influencing

Negotiating (IS/CS/Eng): Negotiation is the process of discussing and bargaining between two or more parties with different interests and viewpoints, in order to achieve a common ground. In the context of Industry 4.0 it plays an important role in being able to establish relationships with partners that play a role in the network of Industry 4.0 and customers and be able to negotiate with them (Gray, 2016; Gudanowska, 2017; Vaidya, Ambad, & Bhosle, 2018). Gray (2016) mentions negotiating as an important competency for Industry 4.0. This competency should be present in all three areas including IS, CS and Engineering and can be strongly related to compromising ability. Similar to it, it was not directly mentioned in the focus groups, although it can be implied by discussions around teamwork.

Emotional Intelligence (IS/CS/Eng): Emotional intelligence describes the ability to influence the own feelings and understand and influence the feelings of others. In a managerial or leading position in Industry 4.0 it is important to be able to have a developed form of emotional intelligence in order to influence the own feelings as well as understand and manage the feelings of the others in the organization. This competency is important for all three areas. And although it is more relevant for people in managerial roles, it would be helpful also in other roles and positions in the company. Gray (2016) mentions it as a competency for Industry 4.0, while similar to negotiation it was not mentioned in the focus groups.

3.3 Presenting and Communicating Information

Presentation and Communication Ability (IS/CS/Eng): Presentation and communication ability includes a set of skills that is necessary in order to successful transmit information orally to other people. Especially in leading and managerial positions in Industry 4.0 it is an important competency that makes it possible to set the basics to exchange information, communicate a vision and take the next steps for decision making (Blanchet, Rinn, von Thaden, & de Thieulloy, 2014; Gudanowska, 2017; Mäkiö-Marusik, 2017). This competency is important for each of the analyzed areas with regards to Industry 4.0 including IS, CS and Engineering and also for each role in the company. Blanchet et al. (2014) mention presentation ability as a competency for Industry 4.0. Also in the focus groups it was mentioned by the participant in connection with teamwork: *“... work in team and present the results…*”

4. Analyzing and Interpreting

4.1 Writing and Reporting

Targeted/Technical Communication (IS/CS/Eng): Targeted or technical communication ability includes the competency of communicating and discussing about technical topics, including IT, technology, information systems etc. In Industry 4.0 technology plays a central role, therefore technical communication is an important competency for every employee in the environment. This competency is also important for all three areas IS, CS and Engineering that are analyzed in this thesis as well as for every role in the organization. The literature mentions this competency as important (Erol et al., 2016; Xia, 2011), while in the focus groups it was mention in context of IT affinity, however not exclusively as a competency.

Literacy (IS/CS/Eng): Literacy defines the competency of being able to understand, communicate and gain useful and complex knowledge through the use of computers and technology. In the context of Industry 4.0 where new information is delivered often and the technology advances are big, literacy competency is important for the employees of all three areas IS, CS and Engineering as well as in every role in the company, in order to be able to understand the work processes, interact with the technology, and be able to act accordingly if needed. Xia (2011) mentions this competency in the literature, while similar to technical communication, it was not explicitly mentioned in the focus groups, however it is implied in the context of other competencies as IT affinity.

<u>4.2 Applying Expertise and Technology</u>

IT and Technology Affinity (IS/CS/Eng): IT and technology affinity describes the ability to interact with technology and be able to adapt and learn fast to use and apply new technologies. In Industry 4.0 this competency is important for every employee since the interaction with technology will be high, and many steps of the work will be facilitated through technology. Many authors mention this competency as an important one, since technology builds the core of Industry 4.0 (acatech et al., 2016; Erol et al., 2016; Gebhardt et al., 2015; Gehrke et al., 2015; Guo, 2015; Hartmann & Bovenschulte, 2013; Hoberg et al., 2015; Lorenz et al., 2015). Also in the focus groups it was mentioned as an important competency. *"Just to have the picture. You run through the world and Industry 4.0, you know there are so much sensors."* This competency is important for every area of work and every role in the context of Industry 4.0. There is no task that will be conducted without the support of technology and the employees should be prepared to learn new technologies often. This is valid not only for technical areas but also for less technical ones.

Economics (IS/CS/Eng): The competency of economics includes all the set of skills that describe a general understanding of business and business structures, including a general understand of organizational, financial, managerial and technical topics connected to the organization. This competency is important for Industry 4.0 since the environment becomes very interdisciplinary and in order to be successful a combination of technical and business knowledge is required. A basic of economics competencies is required for all employees of IS, CS and Engineering. Depending on the exact role, for some employee's e.g. IS specialists or persons in leading roles, this competency should be more distinctive than for others. This competency was mentioned in the literature (Grimheden & Törgren, 2014; Maenpaa et al., 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018) and it was very widely discussed in the focus groups as an important aspect of Industry 4.0. *"We are looking for students start working in a company and can make new combinations to position themselves best on the market, innovative* *ideas, just showing them these ideas and breaking it down so they can build different combinations." "…who have understand business set of rules…".*

Extract Business Value from Social Media (IS/CS/Eng): Social media are wide spread and have an influence not only for personal usage but also for businesses, where their presence and impact is becoming more and more relevant. In Industry 4.0 where digitalization, communication and servitization are the basics of the economy, social media should be used to achieve business value. Indeed many scenarios are possible through social media. From the possibility to launch marketing campaigns or directly selling products to the possibility to study customer needs and desires and address them for designing or improving the products. Therefore the ability to extract business value from social media is important for all three groups, namely IS, CS and Engineering, since it brings a big change to the society. Authors from scientific and practitioners literature mention the importance of being able to use social media to achieve a value for the company (Erol et al., 2016; Hoberg et al., 2015), as an important competency for Industry 4.0. Since the topic of social media is in general very hot in the public it was also very broadly discussed in the focus groups in relation with ethical questions of data privacy. *".. it would be important to use Facebook data, which is a combination of text, photos and maybe geodata … and use data analytics on it"; "…. we want to gain information, without losing any part of it, but we should be careful so that you cannot find out who was the person that posted it…".*

Service Orientation/Product Service Offerings (IS): Services and product service offerings will gain a new importance in the era of Industry 4.0. The products will be equipped with sensors and apart from the products, organizations will offer also additional services that are e.g. possible through analyzing sensor data. Therefore it is important for employees especially in the IS discipline, to have an understanding and instinct about this kind of solutions. This competency is needed especially for employees for the IS discipline that are in roles where they directly interact with these solutions. The results of the literature also underline the importance of this competency for Industry 4.0 (acatech et al., 2016; Chunzhi, Hui, & Xia, 2012; Hoberg et al., 2015; Gudanowska, 2017; Klinkel, et al., 2017; Mabkhot, et al., 2018; Zinn, 2015). The competency was also part of the focus group discussions: "*The question is: Which potential does the digitalization bring and which new services can be offered based on that?*"

Business Process Management (IS): Business process management competency describes the ability to identify, evaluate or improve processes. In Industry 4.0 the work will become even more complex and the services will be more and more interconnected and automated. Therefore business process management capacity is necessary in order to understand and improve the processes to achieve a value for the organization. Since this competency is mainly of an organizational nature and has a strong connection with economics, it is a competency mostly necessary for IS specialists in roles that directly engage with process improvement as also mentioned in the literature (acatech et al., 2016; Blanchet et al., 2014; Erol et al., 2016; Hovanski, et al., 2017; Gehrke et al., 2015; ; Gudanowska, 2017; Kusmin, et al., 2018; Zinn, 2015) and discussed in the focus groups: *"For me is process understanding the most important thing."*

Business Change Management (IS): Business change management competency describes the ability of managing change by reducing resistance and undesired results. In Industry 4.0 many changes will affect the organizations through the introduction of new technologies, new business models and as a consequence new organizational structures. Therefore change management is a competency that should be mastered especially from IS specialists in roles of managing change. In the practitioners literature, Hoberg et al. (2015) mention business change management as a competency that should be acquired to be successful in Industry 4.0. In the focus group discussions this competency was not directly mentioned, however it was implicitly discussed as part of the discussion about managing the digital transformation.

Understand and Coordinate Workflows (IS): Workflows are a sequence of tasks that are conducted to complete a bigger task. In Industry 4.0 since the work will be more and more automated and many tasks will be conducted in a sequence, it is important to own the competency of understanding and being able to coordinate these workflows. This competency is a managerial competency and has a connection with economics, therefore will be required mainly from IS specialists in roles and positions that directly are connected to workflows. In the focus groups this competency was not explicitly mentioned, however it was implied as part of the discussion about business process management. In the literature Xia (2011) mentions this competency as part of the Industry 4.0 competencies.

Network Security (CS): Network security competency involves having knowledge about measures and precautions that can be taken in order to prevent undesired access in computer networks. In Industry 4.0 everything will be connected through networks, so network security is crucial to assure that no breaches are present or manipulations that may lead to undesired results. This is a competency that should be brought mainly from CS specialists since it is a technical task in IT. Mainly CS roles that are directly involved in networks and security should bring this competency. As mentioned in the focus groups: *"Security is becoming much more important than in our classical systems"* In the literature it was also mentioned that IT/CS specialists should have knowledge of digital security, including data and network security (acatech et al., 2016; Chunzhi et al., 2012; Grega & Kornecki, 2015; Gudanowska, 2017; Hoberg et al., 2015; Kusmin, et al., 2018; Mäkiö-Marusik, et al., 2018; Vaidya, et al., 2018; Veile, et al., 2018; Zinn, 2015) .

IT Architectures (CS): IT architectures competency describes the ability to understand and be able to make decisions about IT architectures. In Industry 4.0 this becomes important since the IT architectures become more complex due to arising number of devices connected through a network. This means that CS specialists who are directly involved in this technical IT issues should bring knowledge about IT architectures, especially if they act in roles directly related to the architectures. The competency was not mentioned in the literature. While in the focus groups this competency was mentioned as part of the discussions about cloud computing.

Machine Learning (CS): Machine learning competency is characterized by the ability to have knowledge about the concepts and usage possibilities of machine learning. In Industry 4.0 this discipline of CS will be on the focus and be used for smart machines in order for them to improve themselves. This is a discipline of CS therefore a necessary competency for CS specialists involved directly with machine learning. The competency was mentioned in the focus groups in the context of in-memory DBs and data analytics, while it was not mentioned in the literature.

System Development (CS/Eng): System development describes the competency of planning, creating, testing and deploying IT systems used in an organization. This will be a core competency in Industry 4.0 in order to be able to develop the smart systems that will be used in the factory of tomorrow. Since this is a competency of a technical nature it is relevant for CS and Engineering specialists directly involved with system development activities. As mentioned by Grega & Kornecki (2015), Grimheden & Törgren (2014) and Maenpaa et al. (2015) this competency will gain a significant importance in Industry 4.0. Also in the focus groups the competency was broadly discussed: *"The more technical people should know afterwards how to create systems."*

Integrating Heterogeneous Technologies (CS/Eng): The competency of integrating technology describes the ability to know interfaces of different vendors and technologies and be able to integrate them in a cooperating system from hardware and software perspective. In Industry 4.0 the technology integration will be on the focus as part of machines networks and automation that will occur. In the literature it is mentioned that while working with engineers both groups of CS and Engineering should bring the competency of integrating heterogeneous technologies (Grega & Kornecki, 2015; Grimheden & Törgren, 2014; Klinkel, et al., 2017; Maenpaa et al., 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018). In the focus groups this competency caused also a debate, mainly with the focus on interfaces: *"I think the interface knowledge is missing as well"*

Mobile Technologies (CS/Eng): Mobile technology competency describes the knowledge about using, developing and applying mobile technology solutions to achieve a value for the organization. In Industry 4.0 mobile technology will play a big role, and most of the actions will be conducted mobile. Therefore this competency is required from employees of the CS and Engineering disciplines that interact with mobile technologies. Hoberg et al. (2015) mention the ability to use knowledge about mobile technologies as important Industry 4.0 competency, while in the focus group discussions it was also mentioned and discussed from the participants: *"I think it would be exiting to learn to develop apps for different purposes".*

Sensors/Embedded Systems (CS/Eng): Sensors/embedded systems competency describes the knowledge about using, developing and applying sensors and embedded systems solutions to achieve a value for the organization. In Industry 4.0 sensors and embedded systems will be everywhere. Machines will talk to us through sensors, so this competency is very important for CS and Engineering specialists acting with these solutions. (Grega & Kornecki, 2015; Koska, et al., 2017; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018) As mentioned by Grega and Kornecki (2015) knowledge about sensors and embedded systems will be important in Industry 4.0. This topic was also broadly discussed in the focus groups: *"Just to have the picture. You run through the world of Industry 4.0 and you know there are so much sensors."*

Network Technology/M2M Communication (CS/Eng): This competency describes the ability to understand network technology and M2 M communications, and be able to use and apply these technologies in scenarios where they are needed. In Industry 4.0 all the machines will be connected through a giant network and will communicate with one another, therefore this competency is important for CS and Engineering specialists working in the area. As mentioned in the literature (acatech et al., 2016; Blanchet et al., 2014; Chunzhi et al., 2012; Erol et al., 2016; Gebhardt et al., 2015; Klinkel, et al., 2017; Koska, et al., 2017; Zinn, 2015), knowing network technology and M2M communication will be important in Industry 4.0. This discussion was also conducted in the focus groups: *“Technology communicates with each other..”*

Robotics/Artificial Intelligence (CS/Eng): Artificial intelligence competency describes the ability to understand and apply artificial intelligence related solutions in Industry 4.0 scenarios. This competency plays a role in Industry 4.0 as also mentioned in the literature (acatech et al., 2016; Ansari, et al., 2018; Hartmann & Bovenschulte, 2013; Klinkel, et al., 2017; Lorenz et al., 2015), since many steps of the work will be conducted by intelligent machines, that need to be built, programmed and maintained. Therefore this competency is important for CS and Engineering specialists, directly engaging with these topics. Although this competency is important it was not explicitly mentioned in the focus groups, however it was implied as part of the discussion about predictive maintenance, machine learning and data analytics.

Predictive Maintenance (CS/Eng): Predictive maintenance competency is characterized by the capability of knowing and applying predictive maintenance tools and solution patterns. In Industry 4.0 predictive maintenance is seen as one of the main characteristics, therefore the academics with a technical background as CS and Engineering specialists, who are in positions to deal with predictive maintenance will be required to bring predictive maintenance competency. The competency was discussed in the focus groups. *”Yes to analyze the data. And figure out when are the best windows for maintenance. So you can just minimize the set down of your high productive assets” “The machine will say: “Oh, it is time to maintain me.”* The competency was not mentioned in the analyzed literature.

Modelling and Programming (IS/CS): Modelling and programming describes the ability to abstract situations and be able to implement them in a programming language. In Industry 4.0 this competency will become even more relevant, since the work will be conducted by intelligent machines that need to be programmed. This is an IT related competency therefore relevant for the groups of IS and CS specialists. While programmers should have a very deep level of this competency, every academic should have a basic understanding of programming and programming concepts, since this helps to better understand the technology and how it works. As mentioned by Erol et al. (2016): “…knowledge about state-of-the art software architectures, modelling and programming techniques” is important. Also other authors (Chin & Callaghan, 2013; Erol et al., 2016; Gehrke et al., 2015; Klinkel, et al., 2017; Kortuem et al., 2013; Kusmin, et al., 2018; Lorenz et al., 2015; Mäkiö-Marusik, 2017) mention modelling and programming knowledge as a competency for Industry 4.0. This competency was also mentioned and discussed from the focus group participants: *„We need people who can program a little”.*

Big Data/Data Analysis and Interpretation (IS/CS) Big data and data analysis and interpretation is a competency needed from IS specialists as well as computer scientists. This competency describes the ability to make sense of the gathered data from different sources. It may include the analysis of structured and unstructured data, by modelling them properly and applying different algorithms to deliver results that can be used in different contexts. In the focus groups this was the top, most mentioned competency. *“Data analytics is very important” “Skills to analyze data and prediction are important”.* Various authors (acatech et al., 2016; Bechtold, Lauenstein, Kern, & Bernhofer, 2015; Blanchet et al., 2014; Erol et al., 2016; Gehrke et al., 2015; Hoberg et al., 2015; Kaiser, et al., 2018; Klinkel, et al., 2017; Lorenz et al., 2015; Mabkhot, et al., 2018; Müller, et al., 2018; Vaidya, et al., 2018; Sreedharan, & Unnikrishnan, 2017; Zinn, 2015) from the literature as well many practitioners mention data analytics as an important competency. This competency is a domain related competency and not a behavioral one, and is of higher relevance for employees in positions related to IT. Therefore in the context of the proposed competency model, it is considered as relevant for IS and CS specialists since this areas are strongly related to IT. Furthermore depending on the positions, specialized roles as data scientists and analysist need a more distinct competency in this area than others.

Cloud Computing (IS/CS): Cloud computing competency describes the ability to understand, model and simulate the advantages and disadvantages that may come from moving services and data in the cloud. This includes a basic knowledge of data security and privacy combined with legal aspects. In Industry 4.0 the organizations will become even more specialized, and the quantity of generated data, e.g. through sensors will arise. Therefore cloud computing competency plays a role for Industry 4.0. Since cloud computing is about IT, the professionals of IS and CS are the ones that should bring this competency. This includes roles that are directly engaged with activities related to cloud computing providers. In the literature (acatech et al., 2016; Chunzhi et al., 2012; Hoberg et al., 2015; Koska, et al., 2017; Mabkhot, et al., 2018; Müller, et al., 2018; Sreedharan, & Unnikrishnan, 2017; Vaidya, et al., 2018) the relevance of cloud computing and cloud architectures knowledge for Industry 4.0 is widely mentioned. In the focus groups cloud computing knowledge was also part of the discussion and mentioned as a competency for Industry 4.0: *"Cloud for services, cloud for customers…should learn that… this is very powerful".*

In-Memory DBs (IS/CS): In-memory DBs competency describes the ability to understand the principles of in-memory DB and be able to see its advantages and disadvantages given a certain situation. In Industry 4.0 the quantity of data will grow, and real time connection and response is part of the architecture, therefore in-memory DBs will gain a broad application and usage. This means that specialists from IT disciplines as IS and CS should bring a basic understanding about in-memory technology in order to be able to judge if the technology should be used or not. For specific roles, that will implement and use the in-memory DBs a deep level of the competency is required. In the practitioners literature, Hoberg et al. (2015) mention this competency as part of the Industry 4.0 competencies. While in the focus groups the discussion about in-memory was large and mainly focused on the in-memory technology offered from SAP, HANA: *"I think not only analytics, but learning about web apps, mobile apps etc., based on HANA…"*

Statistics (IS/CS): Statistics competency in this context describes a basic understanding of statistics that can be used and applied for decision making in certain situations in Industry 4.0. As extracted from the literature and focus groups, a basic knowledge of statistics is needed especially for IS and CS specialists. As VDI (2015) mentions statistical knowledge is required for judging challenges that will arise in the factory of the future. In the focus groups this was also part of the discussion: *"We need statistics know how for information system specialists"*

Data Security (IS/CS): Data security knowledge includes an understanding and awareness about data security as well as ways to avoid possible breaches. In Industry 4.0 everything will be interconnected, and a permanent data exchange will exist. It means that the importance of protecting data becomes even more relevant, since security breaches could bring to undesired or even threatening outcomes. Since this topic is mainly IT related it is a competency that should be mastered from IS and CS specialists, and while every employee in every role should bring a basic understanding on it, employees that are directly engaged in these topics should be more specialized. acatech et al. (2016) mention the importance of data security competency for Industry 4.0. Also in the focus groups this competency was part of the discussions and mentioned as important for Industry 4.0: *"…to give them the whole picture what you can do with it but it is also the downside of the things that you have to arrange for data security."*

<u>4.3 Analyzing</u>

Problem Solving (IS/CS/Eng): Problem solving consists in applying methods in order to solve problems. It is a crucial competency in Industry 4.0 for the employees of every area and role in the organization. In Industry 4.0 employees will be faced with new technologies and therefore, often new problems will arise. The ability to apply problem solving is therefore important in an Industry 4.0 work environment. As mentioned by Erol et al. (2016): "human flexibility in problem solving and creativity, ability to communicate complex problems" will be important. Also other authors agree with problem solving as an important competency for Industry 4.0 since work and cooperation will become more complex, therefore Industry 4.0 will require academics with analyzing competencies like problem solving (acatech et al., 2016; Erol et al., 2016; Gebhardt et al., 2015; Gray, 2016; Gudanowska, 2017; Kiesel & Wolpers, 2015; Klinkel, et al., 2017; Mäkiö-Marusik, 2017 ; Richter et al., 2015; Smit et al., 2016; Windelband, 2014). This competency will be of relevance for the employees of all the three areas IS, CS and Engineering and for every role in the company. This competency was not explicitly mentioned in the focus groups but implied in the discussions about programing, modelling and data analytics.

Optimization (IS/CS/Eng): Optimization describes finding an alternative to a certain solution that has lower costs, a higher performance, or minimized undesired results. In Industry 4.0 the products and solutions will become personalized and adapted to the needs of each customer, therefore optimization plays a role, in order to keep each customer satisficed but minimize the costs. Therefore acatech et al. (2016) and Gebhardt et al. (2015), agree that this competency is relevant for Industry 4.0. The optimization competency has a relevance in all three areas analyzed in this thesis. However not every role needs to bring optimization competency but only employees in certain specialized areas. This competency was not mentioned in the focus groups.

Analytical Skills: The analytical skills include the ability to understand, analyze, conceptualize or solve complex problems given a certain amount of information. In a complex work environment as Industry 4.0, analytical skills are needed to understand and solve arising challenges. This competency is needed from all three areas analyzed in the thesis including IS; CS and Engineering in every role in the company. Many authors (Erol et al., 2016; Hartmann & Bovenschulte, 2013; Kusmin, et al., 2018; Lorenz, Rüßmann, Strack, Lueth, & Bolle, 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018) mention the importance of analytical skills in the context of Industry 4.0. This competency was not explicitly mentioned in the focus groups, however it was implied in the discussion about programming and data analytics.

Cognitive Ability (IS/CS/Eng): The cognitive ability includes the ability to combine and solve different tasks by combining many competencies to support them. This ability is necessary in an Industry 4.0 environment (Gray, 2016; Gudanowska, 2017) in order to solve arising challenges and be able to adapt in critical situations. Regardless of the area, this competency is necessary for every employee in every role in the company as mentioned in the literature by Gray (2016). This competency was not directly mentioned in the focus groups, however, similar to the analytical skills, it was implied in the discussion about programming and data analytics.

5. Creating and Conceptualizing

5.1 Learning and Researching

Life-Long Learning (IS/CS/Eng): Life-long learning includes the process of self-motivated pursue and adaption of knowledge for personal or professional reasons. In the context of Industry 4.0 the technological development is big. The employees are confronted daily with new technology, changing processes and products etc. Therefore the employees should be able to pursue lifelong learning and be opened and motivated to capture and adapt new knowledge. This competency is important for every area and every role in Industry 4.0 As Kiesel and Wolpers (2015) describes "… new demands on individuals is the need of being able to learn quickly and self-organized the core content of specific knowledge fields while managing and mastering the vast amount of information". Academics should be able to always adapt to the newest technologies and make the most out of them as many authors agree (Blanchet et al., 2014; Erol et al., 2016; Gebhardt et al., 2015; Gehrke et al., 2015; Grega & Kornecki, 2015; Kiesel & Wolpers, 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018; Lorenz et al., 2015). However in the focus groups, this competency was not mentioned or discussed from the participants.

Knowledge Management (IS/CS/Eng): Knowledge management is the process of creating, using, sharing and managing the knowledge in an organization (Krcmar, 2015). Employees with knowledge management competency are able to apply the necessary tools, methods and techniques to fulfil the knowledge management process in an organization. In Industry 4.0 new knowledge is generated continuously. The technical environment is very volatile, which brings often to changes, developments and new methods and products. To be able to capture and build on the created knowledge, employees should bring knowledge management competency. This competency is relevant in all areas and roles in Industry 4.0 however specialized employees need a more distinct competency than others. Authors in the literature (Gehrke et al., 2015; Kiesel & Wolpers, 2015) mentioned knowledge management as an important competency. While this competency was not mentioned in the focus groups.

5.2 Creating and Innovating

Innovating (IS/CS/Eng): Innovation is the process of delivering new products or services or improving existing ones. The innovating competency is the ability to recognize the innovation potential and apply appropriate methods and tools to materialize it in new or improved products and services. In Industry 4.0 the discussion is about new technologies, new services, new business models and new processes with the use of automation, sensors, networks etc. Therefore the innovating competency is crucial in Industry 4.0 in order to be able to recognize the potential of the developments and turn them in concrete outcomes that would bring a benefit to the company. This competency should be present in all three analyzed areas of Industry 4.0 especially in leading roles. Authors in the literature (acatech et al., 2016; Stocker et al., 2014) agree that innovating competency is important for Industry 4.0. While also in the focus groups it was mentioned in connection with developing new business models, where innovation capability plays an important role.

Creativity (IS/CS/Eng): Creativity describes the ability to perceive situations in new ways and find hidden patterns and develop ideas in order to generate solutions. In order to use new technologies in Industry 4.0 to develop new products, business models and solutions, creativity is an important ability for all three analyzed areas as IS; CS and Engineering. It is also important in every role in the company and was mentioned in the literature as an important competency for Industry 4.0 (Erol et al., 2016; Kiesel & Wolpers, 2015; Kusmin, et al., 2018; Mäkiö-Marusik, 2017; Richter et al., 2015; Stocker et al., 2014). In the focus groups, creativity is mentioned in connection with business model development and innovation competency as this competencies are strongly correlated with one another.

Critical Thinking (IS/CS/Eng): Critical thinking describes the ability to examine situations, issues and ideas and form a judgment. This ability plays a role in Industry 4.0 since it is important to analyze the new technologies and situations that arise from them and decide if they can be applied or not or if they bring any potential or value for the organization (Gudanowska, 2017; Kiesel & Wolpers, 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018). This competency should be present in all three areas IS, CS and Engineering as well as in every role that the employees have in the company. Kiesel and Wolpers (2015) mention critical thinking as a competency for Industry 4.0. It was also discussed in the focus groups *“.. to think what are my possibilities and what is my goal. Critical thinking”* .

Change Management (IS/CS/Eng): Change management describes the capability of applying the necessary tools, methods and techniques in order to introduce change in an organization in form of a new approach, new structure, technology etc. Industry 4.0 is all about change and introducing new technologies or approaches in various aspects. Therefore there is a need for employees with the competency to manage change accordingly (Hoberg et al., 2015; Hovanski, et al., 2017; Gudanowska, 2017). As Hoberg et al. (2015) mention, change management gains a new importance in the context of Industry 4.0. This competency plays a role for all the areas IS; CS and Engineering and every role in the company should be opened and prepared to embrace change. However the ability to manage change is only needed for specific employees who are in positions to manage change. This competency was however not mentioned in the focus group discussions.

5.3 Formulating Strategies and Concepts

Business Strategy (IS/CS/Eng): Business strategy is defined as the long term goals of a company. In this context the business strategy competency describes the ability to formulate, follow and accomplish business strategy in an organization. Since Industry 4.0 is accompanied with new technologies and developments that bring new business models and redefine and reorganize the company goals, business strategy changes and business strategy competency wins therefore a new importance. Zinn (2015) mentions business strategy as an important competency for Industry 4.0. It is important for all three areas analyzed in the competency model. This competency is however necessary only for managerial and leading roles that engage with strategic issues in the company and not for every role. In the focus groups, business strategy competency was mentioned as part of the discussion about business models.

Abstraction Ability (IS/CS/Eng): Abstraction ability describes the ability to adapt ideas and situations and create concepts and generalizations out of them. In Industry 4.0 the variety of situations is very vast, e.g. due to personalized products, each time that an error occurs it is unique in its kind. However due to abstraction ability, employees are able to generalize the problem and adapt a known solution for that. This ability should be present in all the employees of the three groups IS, CS and Engineering. However not every role needs a high degree of abstraction ability. This ability is more necessary for employees in leading roles. This competency is also widely mentioned in the literature (Erol et al., 2016; Smit et al., 2016; Windelband, 2014), while it did not come up in the focus group discussions.

Managing Complexity (IS/CS/Eng): Managing complexity is the ability of following a holistic approach in managing and leading very different aspects of a complex enterprise, project etc. The work situation in Industry 4.0 becomes very complex. The employees will have to deal with highly complex systems and situations, therefore the ability to deal with complexity and be able to address and manage the challenges is important in Industry 4.0 as also mentioned in the literature (Erol et al., 2016; Gudanowska, 2017; Smit et al., 2016; Windelband, 2014). This competency should be present in the employees of all the three areas, IS, CS and Engineering, especially in leading roles. In the focus group discussions this competency did not come up directly.

6. Organizing and Executing

6.1 Planning and Organizing

Project Management (IS/CS/Eng): Project management ability includes the application of knowledge, skills, tools and techniques to meet project goals. It includes all steps from initiating, planning, executing, monitoring and controlling and closing a project. In Industry 4.0 many of the steps to introduce a new technology, a new business model or a new work process in a company will be conducted as projects. Therefore this competency is important for all the three areas addressed in this thesis as IS, CS and Engineering. However not every role in the organization needs to apply this competency but only specific roles that are directly involved with project management activities. In the literature project management (Grimheden & Törgren, 2014; Gudanowska, 2017; Maenpaa et al., 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018) was mentioned as a necessary competency for Industry 4.0, while in the focus groups the participants combined it with team work competency: *".. conduct projects in teams…"*.

Planning and Organizing Work (IS/CS/Eng): Planning and organizing work is a competency that similar to project management falls in the managerial competencies in the category of planning and organizing. It involves the ability to support the organization by planning, organizing and monitoring employees as well as allocating resources and establish goals and objectives. This competency will be relevant in all three areas IS; CS and Engineering that are analyzed in this thesis, however similar to project management it will only play a role for employees that are actively involved in planning and organizing activities. As Kiesel and Wolpers (2015) mentions: "A person skilled in self-regulation is meta-cognitively, socially, motivationally and behaviorally active when performing tasks like planning, time managing, integrating and organizing knowledge, establishing a productive work environment, using social resources effectively, and experiencing a positive anticipation about the potential learning outcomes". Other authors (Guo, 2015; Hartmann & Bovenschulte, 2013; Kiesel & Wolpers, 2015) also agree with the importance of this competency in the context of Industry 4.0. While in the focus groups the competency was not explicitly mentioned, however it is implicitly derived from the discussion about project management competency.

Management Ability (IS/CS/Eng): This competency includes the ability to make business decisions and lead other employees and allocate resources in an organization. This competency is very strongly related with the two others mentioned above as project management and planning and organizing. And similar to the other two is relevant for all three areas analyzed in this thesis as IS; CS and Engineering, however only for specific managerial roles. The management ability is mentioned in the literature (Gudanowska, 2017; Smit et al., 2016), while it was not explicitly mentioned in the focus groups but could be derived from the discussion about project management.

6.2 Delivering Results and Meeting Customer Expectations

Customer Orientation (IS/CS/Eng): Customer orientation includes the activities followed by an organization to consider the customer's needs and satisfy their major priorities. The customer orientation competency includes the ability to communicate and understand the customers and interact with them in order to fulfil their needs according to the business goals. In Industry 4.0 due to sensors and servitization, the products become more personalized. Each customer is unique and has unique needs, therefore customer orientation plays an important role in order to be able to accomplish the needs of each customer. This competency is relevant for all three areas analyzed in this thesis as IS, CS and Engineering. However, although every role in the company need to have a basic customer oriented thinking, this competency is mostly relevant for employees who engage in activities with customers. This situation is presented also in the literature, where (acatech et al., 2016; Guo, 2015; Klinkel, et al., 2017) agree that customer orientation is a competency of relevance. Also in the focus groups the participants mentioned that social media information can be used to understand customer needs and improve products.

Customer Relationship Management (IS/CS/Eng): Customer relationship management includes all activities conducted by a company to manage the interaction with current and potential customers. This competency is strongly related with the customer orientation as mentioned above as well as with maintaining customer relationships competency and gains a new importance in Industry 4.0, since products are personalized and each customer has unique needs. So it is even more important to interact in a personalized way with each of the customers. Similar to the other two competencies it is needed in all three areas analyzed in this thesis, and although each employee should bring basic competency of customer relationship management, it is mainly relevant for employees who are in the role of interacting with customers. Similar to customer orientation, the discussion in the focus groups, stressed the importance of customer relationship management, and mentioned that information from social media can be used to improve customer relationships. This competency was only mentioned in the focus groups and not in the literature. So it was added to the results from the focus group discussions.

6.3 Following Instructions and Procedures

Legislation Awareness (IS/CS/Eng): Legal awareness includes a basic information involving issues regarding the law especially with regards to the business that is being conducted. In Industry 4.0 due to the connection, sensory, and automation, topics as ethics and privacy earn a new importance. Therefore employees in all three areas IS, CS and Engineering and especially the ones in managerial roles, should bring a basic knowledge regarding the legal status of different topics and especially topics related to the businesses and technologies that the organization conducts. Authors in the literature (Gehrke et al., 2015; Grimheden & Törgren, 2014; Maenpaa et al., 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018) agree that a basic legal awareness will be important in Industry 4.0. The same situation was also presented in the focus groups. Also in connection with the discussion about privacy, social media usage and ethics. One of the participants suggested: *"I want to come to the legal issue. …I am allowed to use social media data, I am allowed to give this data to a company that analyzed my information?.... Basic knowledge about this legal issues is necessary, especially as an information systems specialist or computer scientist."*

Safety Awareness (IS/CS/Eng): Safety means being protected from harm and non-desirable outcomes. Safety awareness includes being aware of potential harmful situations and taking precautions and acting properly to avoid them. The importance of safety awareness in Industry 4.0 is also recognized in the literature (Grega & Kornecki, 2015; Hartmann & Bovenschulte, 2013), since due to the automation and new technologies, many work steps will be interconnected with machines, so the employees should be aware of the risks this might bring and act properly to protect themselves and others. This competency has a relevance for all the three areas analyzed in the thesis as IS; CS and Engineering and all the roles in a company. However individuals that work or interact with machines should have a more distinct competency of safety awareness. This competency was however not mentioned during the focus groups.

Individual Responsibility (IS/CS/Eng): Individual responsibility is connected with employees taking responsibility for their actions and being able to work independently in the job. In Industry 4.0 this competency relates to the fact that there will be no hierarchies and employees will have more responsibility on the job. Therefore Smit et al. (2016) mentions individual responsibility as a competency for Industry 4.0. This competency was however not mentioned in the focus groups.

7. Adapting and Coping

7.1 Adapting and Responding to Change

Work in Interdisciplinary Environments (IS/CS/Eng): Interdisciplinary environments are environments that combine different disciplines in order to achieve certain goals and fulfil tasks on the job. The difficulty in this context is that employees from a certain discipline develop certain working patterns and learn to communicate and interact in a certain way. It means that it can become difficult if people from different disciplines come together and have to work together. However in Industry 4.0 all environments will be highly interdisciplinary. The work processes will be strongly automated and replaced through machines. This means that the engineers who design the machines will have to work together with the IT people who program them and so on. Therefore in the context of Industry 4.0, interdisciplinary competency plays a highly relevant role as also mentioned in the literature (acatech et al., 2016; Ansari, et al., 2018; Blanchet et al., 2014; Gebhardt et al., 2015; Gehrke et al., 2015; Grega & Kornecki, 2015; Klinkel, et al., 2017; Lorenz et al., 2015; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018; Richter et al., 2015). As Erol et al. (2016) underlines: “For engineers a deep understanding of interrelations between the electrical, mechanical and computer components will be a vital ability”. Also in the focus groups this competency was mentioned and discussed as relevant for the work world of tomorrow. *“I think that the interfaces with other disciplines are very interesting.”* Since every environment will become highly interdisciplinary it means that this competency will be important for all analyzed areas in this thesis as IS, CS and Engineering and every available role in Industry 4.0.

Intercultural Competency (IS/CS/Eng): Intercultural competency describes the ability to communicate and work effectively and appropriately with people of other cultures. In Industry 4.0 the work will become more interconnected and more international. There are no boundaries between nations, and multi-cultural companies as well as cooperation between companies in different countries will be common. In this context the employees should bring the ability of working with people from other cultures, respecting other traditions and being able to communicate properly. This competency is important for every area in Industry 4.0 and every role, since all positions in all areas will become multi-cultural. Many authors mentioned this competency (Erol et al., 2016; Gudanowska, 2017; Guo, 2015; Kusmin, et al., 2018; Xia, 2011), while it was not mentioned during the focus group discussions.

Flexibility (IS/CS/Eng): Flexibility describes the ability to act and adapt the behavior based on the circumstances. As Erol et al. (2016) mentions „The basic assumption of our approach is that human actors in a future production scenario will need specific competencies to cope with the new challenges regarding technological and organizational developments and business models.” Therefore this competency will be of importance for all three areas of Industry 4.0 (Erol et al., 2016; Gudanowska, 2017; Klinkel, et al., 2017; Kusmin, et al., 2018; Mäkiö-Marusik,

2017) and every role. This competency was however not mentioned in the focus group discussions.

Adaptability and Ability to Change Mind-Set (IS/CS/Eng): The ability to change mindset describes an employee who is always flexible, ready to learn and adapt his company to new practices, technologies, knowledge and methods. Industry 4.0 will bring many challenges and will transform whole businesses by changing the way we work and interact, therefore the employees in Industry 4.0 must be able to adapt quickly to new ideas and practices. This competency is important for all areas as IS, CS and Engineering as well as every role in the company, since all the jobs in Industry 4.0 will become volatile, and change often, which requires the employees to also change their mindsets often. Authors in the literature also agree that this competency will have a high importance in Industry 4.0 (Gehrke et al., 2015; Kiesel & Wolpers, 2015; Gudanowska, 2017; Klinkel, et al., 2017), however the competency was not mentioned in the focus groups.

7.2 Persuading and Influencing

Work-Life Balance (IS/CS/Eng): Work-life balance can be described as a balance between work life and private life. The ability to find this balance means in being able to prioritize things properly and invest time also in private interests and the social network apart from work. In Industry 4.0 the society will become even more connected. Everyone will be connected with sensors at any time and will always be online. It means that also in the separation between free time and working time will not always be clear. However it is important to achieve a certain balance for the personal whole being and health. Therefore employees in Industry 4.0 regardless of the area where they act or the role in the company, should be able to find the right work-life balance. A better separation also brings better work results and happier people. Erol et al. (2016) mentioned this competency in the literature, while it was not topic in the focus groups.

8. Enterprising and Performing

8.1 Achieving Personal Work Goals and Objectives

Self-Management and – Organization (IS/CS/Eng): Self-management and – organization competency describes the ability to plan, organize and control the own work by taking responsibility and being able to prioritize the tasks properly. In Industry 4.0 this competency gains an important role, since many of the tasks will be conducted by machines and only a very small group of people will be responsible for certain work processes. It means that the organizations will not have the classical hierarchical structures anymore and the single employees will have more responsibility. Therefore this competency gains a new importance in the context of Industry 4.0 as also mentioned by many authors (Gehrke et al., 2015; Kagermann et al., 2013; Kiesel & Wolpers, 2015; Smit et al., 2016). Kiesel and Wolpers (2015) suggest that employees must be: "…active when performing tasks like planning, time managing, integrating and organizing knowledge, establishing a productive work environment, using social resources effectively, and experiencing a positive anticipation about the potential learning outcomes…". This competency is important for all three areas as IS, CS and Engineering and will be relevant for every role in the Industry 4.0. It was however not mentioned during the focus groups.

8.2 Entrepreneurial and Commercial Thinking

Business Model Understanding (IS/CS/Eng): A business model describes how an organization creates, delivers and captures value. Industry 4.0 brings many new technologies and a re-organization of work processes and therefore also many new business models. Therefore, to fully exploit the potential of Industry 4.0, employees should bring a business model understanding in order to discover new possibilities for bringing value to the organization. This competency is necessary for all three areas, mostly for specific roles that are responsible for creating new business opportunities. Some authors (Blanchet et al., 2014; Zinn, 2015) recognize the importance that business model understanding competency will have in Industry 4.0. The participants of the focus groups also broadly discussed this topic by mentioning its importance for Industry 4.0. *"…new business models, what it means. I have a business in Industry 4.0, what can I do differently?" "We should offer students the possibility to think about new business models themselves."*

Entrepreneurship (IS/CS/Eng): Entrepreneurship is the process of conceptualizing, defining, launching and running a new business. The entrepreneurship competency describes a person that has the knowledge, motivation and capability to recognize business opportunities and be able to carry them out. This may not happen only in a classical way as founding a new company, but also as part of an existing company that launches a new product, service or creates a new branch by exploiting a business opportunity. Since Industry 4.0 brings a change in business models and many business opportunities arise, it is important to have employees that recognize the importance of these opportunities and have the capacity and courage to carry them out. The literature mentions entrepreneurship (Gudanowska, 2017; Kiesel & Wolpers, 2015; Klinkel, et al., 2017; Kusmin, et al., 2018; Mäkiö-Marusik, 2017; Mäkiö-Marusik, et al., 2018) as an important competency for Industry 4.0. Similar to business model understanding, which is very close, this competency is important for all three areas analyzed in this thesis as IS, CS and Engineering. Special roles in the organizations, e.g. employees responsible to recognize new business opportunities, will need a more distinct entrepreneurship competency then others. This competency was also discussed in the focus groups, where the participants mentioned it as important for Industry 4.0. *"We are looking for students start working in a company and can make new combinations to position themselves best on the market, innovative ideas, just showing them these ideas and breaking it down so they can build different combinations."*

3.8 Conclusion

In this chapter competencies for Industry 4.0 were defined and described based on a literature analysis and focus group discussions. A competency model based on the SHL competency framework was developed, containing 69 competencies for IS, CS and Engineering. Most of the competencies are of behavioral nature and relevant for all three areas, while only competencies regarding the domain related knowledge can be partly assigned to a certain area as IS, CS and Engineering. The competencies defined in this chapter are not new, however their combination in the context of Industry 4.0 shows a clear tendency of how the work life will change.

While today most competencies required for specific jobs are domain related as programming, analytics, etc., in Industry 4.0 these competencies will earn a smaller role, while behavioral related competencies as communication or teamwork gain a whole new importance. The reason for this is that in Industry 4.0, many domain related jobs will be replaced by computers, while employees will be responsible for organizing the work and making decisions about the strategy and development of a company.

The results in this chapter also show that while today there is a clear division between disciplines, in Industry 4.0 this will become partly obsolete. Nowadays e.g. if we mention someone from the CS area we have a clear expectation and a set of skills in mind that they should bring. In Industry 4.0 this situation changes. As the results showed the competencies are similar for all three areas. The reason for that is that specialized work will be automated, while the work will become connected and interdisciplinary, where the areas will have a strong connection to one another.

The results in this chapter showed also that there is a need for education concepts and strategies with regards to Industry 4.0, in order to teach the mentioned competencies and prepare the students of today to be qualified workforce for Industry 4.0. There are still few learning concepts that address these competencies. Therefore in the next chapter this research gap will be addressed and discussed.

4 A Competency-Based Curriculum for Industry 4.0

4.1 Introduction

In the first part of this thesis a competency model for Industry 4.0 was defined. In this model a set of competencies is described that will be relevant and should be mastered by employees in Industry 4.0, depending on their job and role in the company. However defining the needed competencies for Industry 4.0 is just the first step in building the workforce of the future. It is even more important to address and teach these competencies to students who will be the employees of tomorrow. Kagermann et al. (2013) pointed the qualification of employees with the right competencies as one of the key success factors for Industry 4.0. As McKinsey (2015) mentions, companies will need to expand the competencies of their employees by hiring employees with a new set of competencies. The workforce for Industry 4.0 needs to be prepared with the right competencies for Industry 4.0 therefore universities need a clear definition of the competencies (Jaschke, 2014; Richert et al., 2016; Richter et al., 2015). A further challenge lies in preparing students and workforce in adapting these competencies through dedicated teaching concepts and curricula for Industry 4.0 (Richter et al., 2015). Prifti, Knigge, Löffler, Hecht, et al. (2017) suggest that education concepts and curricula for actual topics as Industry 4.0, the IoT, or the Digital Transformation (DT) should be on the top priorities of education provisioning.

However there are few curricula dedicated to Industry 4.0 or related concepts as IoT or the DT. Most of the curricula focus on a certain aspects of Industry 4.0 as cyber physical systems, security, sensors etc., but do not give the whole picture of Industry 4.0. Furthermore the offered curricula are not competency-based. In order to complete and fulfil the education for Industry 4.0 it is important to offer competency-based curricula to the students. This has many reasons:

- In order to be able to better address the competencies of Industry 4.0 and have a prepared workforce for the work of tomorrow, goal specific curricula should be offered. In this way it can be assured that the employees of tomorrow are educated with the necessary set of competencies and able to master the challenges of the work of tomorrow.
- One of the results of RQ1 showed that most of the requested competencies are of a behavioral nature, while the nature of teaching in universities today is often based in domain specific knowledge. Therefore competency-based curricula could be developed and applied in order to address behavioral competencies.
- The experience has shown that competency-based teaching e.g. based on predefined learning outcomes delivers better results. This result has been proven in many countries as the Netherlands or Denmark. Through competency-based teaching and clear predefined learning outcomes, students are able to learn better and achieve better results. Furthermore this is a requirement of the Bologna process that many European universities are undergoing (Schaper et al., 2012).

Therefore in this research the focus will be on competency-based teaching for Industry 4.0. After defining the competencies in RQ1, a teaching concepts for Industry 4.0 that focuses on the target groups of this thesis which includes IS; CS and Engineering students is delivered. In this context a curriculum for Industry 4.0 is developed, by choosing the necessary teaching methods and tools that address not only domain knowledge but also behavioral competencies.

4.2 Methods for Curriculum Development

In this thesis a comprehensive and holistic curriculum covering topics of the Digital Transformation towards Industry 4.0 was developed. The overall development was conducted by following the six phases approach proposed by Schaper et al. (2012) . During the development phases itself, further methods, approaches and theories were also applied. In this section these methods are described.

4.2.1 Curriculum Development according to Schaper et al. (2012)

In Chapter 2.2.2 Models of Curriculum Development, models and approaches for curriculum development were analyzed. Many of the models suggest in defining learning outcomes based on taxonomical criteria at the beginning of curriculum development. However they are not competency-based. Since one of the goals of this thesis is in developing a competency-based curriculum, the approach suggested by Schaper et al. (2012) that offers a didactical approach for competency-based curriculum development was applied.

In their study Schaper et al. (2012) analyses the importance of competency-based teaching. They underline its importance and suggest in developing competency-based curricula. Therefore they define a six phase approach for competency-based curriculum development that includes content and conceptual as well as organizational steps. Schaper et al. (2012) follow a holistic view on competency-based curricula development. Their study offers suggestions for developing curricula and also whole courses of studies that are competency-based. The authors also suggest how a new curriculum or even a whole new course of studies should be introduced in a university from an organizational point of view.

In the case of this thesis the focus lies on the content and conceptual aspects of curricula development, since the goal is to offer a curriculum for Industry 4.0. The introduction steps are not of relevance since they depend on the universities where the curricula is being introduced. Furthermore in the context of this thesis as described in 2.2.3 Curriculum Concept in the Context of this Thesis, a curricula is not a course. In this thesis a curriculum is “as a collection of documents aiming in delivering a structured series of learning experiences that includes theoretical and practical content to deliver predefined competencies in form of learning outcomes to the learner”.

Therefore the organizational steps are not needed and only the conceptual steps for the curriculum development are applied – see Table 5.

Table 5: Didactic Approach for Competency-Based Curriculum Development (Source: Own Representation Based on Schaper et al. (2012))

Conceptual Step	
Phase 1	• Determination of qualification objectives or competencies
Phase 2	• Definition of learning outcomes for the curriculum, based on taxonomical criteria and systematics
Phase 3	• Planning of the learning units for the curriculum • Definition of the learning outcomes for each learning unit • Conceptualization of the single learning units • Conceptualization of the teaching methods for each learning unit
Phase 4	• Development of learning units content including theoretical and practical part
Phase 5	• Development of accompanying measures for the implementation of the curriculum e.g. mixing teaching methods, describe how a lecturer could conduct his lecture
Phase 6	• Development of evaluation mechanisms for each of the learning units in order to measure if the intended learning outcomes and competencies were achieved

In the first phase it is important to define the competencies that the students should adopt at the end of the course. Competencies and qualification goals that will help the students to succeed afterwards as employees in the Industry 4.0 should be delivered. Depending on the curriculum topic and the direction of studies for which it is offered, different competencies and competency profiles can be defined. While defining these competencies in the context of Industry 4.0, the focus should lie not only on the domain knowledge that should be adopted by the students but also on the behavioral oriented competencies. As Schaperet al. (2012) recommends in this step, it is important not only to look inside the university but also to have a broader view of the competencies required in the economy. Therefore while developing a curricula, competencies that are needed from companies should also be taken into consideration.

Based on the defined competencies, in the second step the learning outcomes for the curricula should be defined. The experience has shown that when curricula are based and built on learning outcomes they deliver better results, motivate the students to learn better and it is easier to evaluate the study success (Schaper et al., 2012). Furthermore Anderson and Krathwohl (2001) recommend how learning outcomes can be defined based on competencies. They define the knowledge dimension and the cognitive process dimension. A detailed description of the Anderson and Krathwohl (2001) taxonomy is provided in 4.2.2.1 Bloom's Taxonomy and the Revised Bloom's Taxonomy. By defining the learning outcomes for the whole curriculum it is easy then to narrow down the goal of the curriculum and to develop the necessary content for it.

Further on, based on the learning outcomes for the whole curriculum, Schaper et al. (2012) recommend in going in a detailed planning for the content parts that should be included in the curriculum. As a first step, based on the learning outcomes Schaper et al. (2012) recommend in planning each learning unit. Furthermore they recommend that the curriculum should be modularly built since it gives more freedom in applying it in teaching. In this context it should be defined how many modules should be part of the curriculum, how many learning units each module includes and what the content for each unit should be. Furthermore the learning outcomes for each learning unit should be defined. Afterwards a high level description of the content for each learning unit as well as of the applied teaching methods should be delivered. With this phase the detailed planning of the curriculum is completed and phase 4 starts, in which the content for the single learning units, including theoretical and practical parts are developed. Therein, the teaching methods planned above should be taken into account.

In step 5, accompanying measures for the curriculum should be developed, e.g. teaching notes for the learning units so that the lecturers are able to better imagine how a learning unit is conducted; introduction videos to concepts and applications, recommendations for mentoring or teamwork and projects etc. Accompanying measures could also include different online tools used for the delivery or evaluation of the curricula.

In the last step of evaluation, Schaper et al. (2012) firstly recommend to test the implemented curriculum with a pilot project. The feedback from the pilot can be applied to further improve the content of the single learning units as well as of the whole curriculum. Furthermore it is recommended to include evaluation mechanisms for each learning unit and evaluate the curriculum in class. Additional evaluation mechanisms as discussions with the lecturers or students could be added.

In this thesis, the six phases approach from Schaper et al. (2012) was applied for developing a curriculum for Industry 4.0.

4.2.1.1 Phase 1: Determination of Competencies

In this step the competencies for the curriculum are determined, where the general goals of the curriculum are set. As Schaper et al. (2012) recommend one of the methods for defining the competencies is by using competency models. Competency models give a structured set of competencies as well as the relationship between them. For the purpose of this thesis a competency model for Industry 4.0 was developed. For developing the model research literature as well as practical literature from the industry was considered. As Schaper et al. (2012) suggest by considering competencies from outside research, it helps in defining competencies that also fulfil the requirements of the industry. In this way it helps in forming future employees with a better set of competencies that are better prepared for the work of tomorrow. To complete these results an empirical data collection method as focus groups was also applied, in order to evaluate and further expand the defined competencies.

The defined competencies were structured in a competency model by using the SHL competency framework. This framework is built on findings of scholars and practitioners and has a broad application in industry. In this way it can be assured that the defined competency model is a state of the art model and also complies with the requirements from practice as suggested by Schaper et al. (2012). This assures that after completing the curricula the students will be prepared as future workforce for Industry 4.0.

A further recommendation of Schaper et al. (2012) suggest that depending on the target group of the curriculum it is recommended to create different competency profiles. By following this recommendation three shapes of the competency model for each of the student groups of the target group that are IS; CS and Engineering were created.

A detailed description of how this step was conducted is provided in Chapter 3 A Competency Model for Industry 4.0. The complete competency model for Industry 4.0 with competencies for three target groups that are IS; CS and Engineering is provided in Chapter 3.6 The Competency Model.

4.2.1.2 Phase 2: Definition of Learning Outcomes

In the second phase the goal is to define the learning outcomes of the curriculum based on taxonomical criteria and systematics. The learning outcomes are the central element of the competency-based curriculum development (Schaper et al., 2012). First, it should be clear what the difference between learning outcome and competency is. In fact many authors use this terms as synonyms (Hollender, Beck, Deneke, Könekamp, & Kriegler, 2010). Others however treat learning outcomes as a complex of competencies, knowledge, abilities and capabilities that are reached as a result of the learning process (Schaper et al., 2012). The discussion on the difference between competencies and learning outcomes is long. For instance, Kennedy (2007) criticizes the concept of competency, since he sees it as not adequately defined, therefore he suggests in using the concept of learning outcome for curriculum development purposes. For the purpose of this thesis competencies are defined as a “sets of behaviors that are instrumental in the delivery of desired results or outcomes” (Bartram et al., 2002), while learning outcomes are concrete goals that should be achieved as a result of the learning process. Learning outcomes can be defined on different levels. They can be defined for the whole curriculum, for a module of the curriculum or for a specific learning unit.

Hubwieser (2001) states that defining the learning outcomes is one of the more important steps while planning the teaching process. He underlines the importance of asking the question: “What do I exactly want to teach with this learning unit?[17]” There are different methods for formulating learning outcomes. However one of the most used and applied approach is the Bloom’s Taxonomy developed in 1956 (Anderson & Krathwohl, 2001). This Taxonomy has been revised 45 years later by Anderson and Krathwohl (2001). In their approach Anderson and Krathwohl (2001) extend the taxonomy and suggest a second dimension for the definition of learning objectives. In this thesis the Revised Bloom’s Taxonomy will be applied since it is a

[17] Was will ich mit *dieser* Unterrichtseinheit *genau* erreichen?

state of the art framework for defining learning outcomes. It is used and applied from universities worldwide and offers a structured and predefined way. A description of the applied taxonomy is provided in 4.2.2.1 Bloom's Taxonomy and the Revised Bloom's Taxonomy.

After defining the competencies for the digital transformation towards Industry 4.0, the goal in this thesis was to develop a competency-based curricula for the digital transformation towards Industry 4.0. The curriculum should include the main terms, aspects, technologies as well as methods and tools for the digital transformation by following the competencies defined before.

Therefore based on the two dimensions of the Revised Bloom's Taxonomy, a list of high level learning objectives for the whole curriculum was defined. The list of the learning objectives is provided while describing the curriculum content in Chapter 4.4.2 Learning Objectives.

4.2.1.3 Phase 3: Detail Planning of the Learning Units

As recommended by Schaperet al. (2012), in this step of the development the following steps are conducted:

- Planning of the learning units for the curriculum,
- Definition of the learning outcomes for each learning unit,
- Conceptualization of the single learning units,
- Conceptualization of the teaching methods for each learning unit.

Details about this process steps and the respective results are provided in the following section as well as in section 4.4 **Curriculum Overview**.

For defining the single learning units, approaches of design thinking for setting the principles of the curriculum and the content of the single learning units were followed. The method as well as the followed approach are described in Chapter 4.2.2.2 Design Thinking.

4.2.1.4 Phase 4: Learning Unit Content

In the step above the learning objectives and intended learning outcomes were defined for each of the modules. At this point the development of the curriculum content started. For developing the content, literature from research and practitioners was taken into consideration. Furthermore, MOOCs and university courses available on the internet were referred.

One of the principles applied in the content development, is the constructive alignment as recommended by Biggs (2003). It is based on the constructivist theory that the learners use their own activities to create knowledge or other outcomes (Biggs, 2003), based on the principle "what the student does is more important that what the teacher does". By applying the constructivism theory, short theory introductions and a variety of practical aspects including exercises, case studies, teaching cases and discussions were developed for each learning unit, in order for the students to be able to learn from their own experience. For making it possible to apply the constructivist approach different methods were applied.

As the results of the first part of this thesis showed, apart from the domain knowledge, behavioral competencies for Industry 4.0 play a central role. Employees in Industry 4.0 will need to bring many behavioral competencies along with the domain knowledge in order to be able to work in the highly complex environments of Industry 4.0. The human will be the center of Industry 4.0, and while the jobs will be conducted by machines, for coordinating, planning and supporting them, the employees will need to be highly flexible, able to work and communicate with others, able to learn fast, adapt to new situations as well as be creative and innovative.

It means that the teaching concepts that are applied in the curricula are not only required to teach domain specific knowledge in traditional form, like learning how to program, or analyze data. The curricula should address a high number of behavioral competencies as an important aspect of the Industry 4.0 education.

However, teaching behavioral competences is often challenging (Cappel & Schwager, 2002; Hackney, McMaster, & Harris, 2003). The experience has shown that by combining interactive teaching methods with classical ones, it is possible to teach students behavioral competences. Therefore, by aiming to offer a curriculum that fulfils the requirements of Industry 4.0, the leaning content was combined with various teaching/learning methods in order to support behavioral competencies. An overview of the applied methods is provided in Chapter: 4.3 Teaching Methods.

4.2.1.5 Phase 5: Accompanying Measures

After developing the content for each module, Schaper et al. (2012) recommends in developing further accompanying measures for each of the learning units. The accompanying measures can be different based on the content that is provided. They can include further literature, further information, supporting tools etc. In the curriculum some accompanying measures were included.

One of the chosen accompanying measures is the delivery form. The whole curriculum is delivered as an interactive **HTML application**. It means that the whole content is delivered in an HTML file and the lecturers can navigate through the HTML and choose the appropriate units for them. There is then a single page for each module where the single units can be accessed. A detailed description is provided in 4.4 **Curriculum Overview**. The HTML offers a **curriculum overview** which is interactive and can be used to navigate through the different sessions of the curriculum. In this way it is easier to gain an overview of the content in order to decide what to use.

Industry 4.0 is a complex area that includes different topics. Each lecturer that applies the curriculum in their class can have a different focus and can choose to focus more on specific topics than others. Therefore predesigned **learning journeys** for specific topics and target groups were provided. A learning journey offers a ready to go combination of content that can be applied directly in class or for self-study. Apart from the learning journeys a **curriculum calculator** is provided. This is a tools to help the lecturers to mix and match the content for designing their course.

A further tool provided is a **glossary** of the main concepts and terms used throughout the curriculum that are also basic concepts of Industry 4.0, IoT and the DT. It helps in easily create an overview

For specific learning units, **lecturer notes** that explain the main points and what is important to be taken into consideration for the respective content is provided. This helps the lecturers while preparing and conducting a lecture. These notes include also instructions on how to solve the presented exercises or case studies or how to assist the students in elaborating a solution.

In order to extent the materials and give the possibility for further qualification, we also provided links to existing content and **MOOCs** with regards to a certain topic. In this way the lecturers and students can chose to get a deeper overview on a topic if needed.

For each learning unit estimated time to complete it, and target group are provided. Furthermore we provide the learning objectives as well as needed prerequisites and tools for each unit. In this way the lecturers can prepare their lecture upfront and have all the necessary information for the preparation at hand.

4.2.1.6 Phase 6: Evaluation

As the last step of the curriculum development phase, Schaper et al. (2012) recommend the evaluation of the curriculum. Schaper et al. (2012) suggest in releasing a pilot first and testing out if the curriculum works as planned and fulfils the goals set while developing it. Afterwards they recommend continuous evaluation and improvement of the curriculum. In this curriculum an extensive evaluation at different steps of the development was conducted. At first the idea was evaluated and improved, afterwards a pilot was released and evaluated. Further evaluation sessions were conducted also after releasing the curriculum. The evaluation is described in Chapter 5 Curriculum Evaluation.

4.2.2 Comprehensive Methods and Theories

4.2.2.1 Bloom’s Taxonomy and the Revised Bloom’s Taxonomy

For defining the learning outcomes as required in the second step of the curriculum evaluation approach, described in Chapter 4.2.1.2 Phase 2: Definition of Learning Outcomes, the Revised Bloom’s Taxonomy was applied. The original Bloom’s Taxonomy was defined for providing learning outcomes and provides six categories of cognitive knowledge that are Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation (Bloom, 1956). The categories were hierarchically ordered by providing an increasing level of mastering a learning outcome from the simplest to the most complex (Figure 13). The hierarchies are cumulative, meaning that if one learning outcome is reached on the level three of application this includes level one of knowledge and two of comprehension (Bloom, 1956). Bloom consideres the Taxonomy as a measurement tool, stating that serves as a:

- “common language about learning goals to facilitate communication across persons, subject matter, and grade levels;

- basis for determining for a particular course or curriculum the specific meaning of broad educational goals, such as those found in the currently prevalent national, state, and local standards;
- means for determining the congruence of educational objectives, activities, and assessments in a unit, course, or curriculum; and
- panorama of the range of educational possibilities against which the limited breadth and depth of any particular educational course or curriculum could be contrasted" (Krathwohl, 2002)

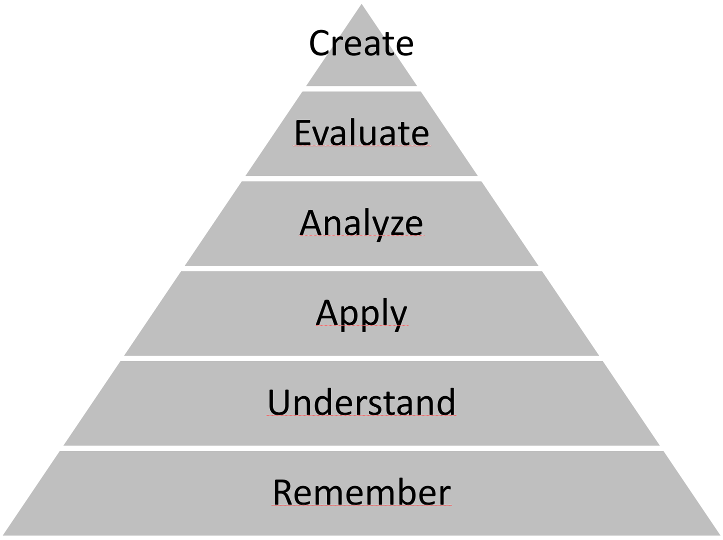

Figure 13: Categories of Cognitive Knowledge.
(Source: Own Representation Based on Bloom (1956))

The full Bloom's Taxonomy with all the cognitive levels and sublevels is provided in the Table 6 below.

Table 6: Structure of the Original Bloom's Taxonomy
(Source: Own Representation Based on Anderson and Krathwohl (2001))

1.0 Knowledge
1.10 Knowledge of specifics
1.11 Knowledge of terminology
1.12 Knowledge of specific facts
1.20 Knowledge of ways and means of dealing with specifics
1.21 Knowledge of conventions
1.22 Knowledge of trends and sequences
1.23 Knowledge of classifications and categories
1.24 Knowledge of criteria
1.25 Knowledge of methodology
1.30 Knowledge of universals and abstractions in a field

		1.31 Knowledge of principles and generalizations
		1.32 Knowledge of theories and structures
2.0 Comprehension		
	2.1 Translation	
	2.2 Interpretation	
	2.3 Extrapolation	
3.0 Application		
4.0 Analysis		
	4.1 Analysis of elements	
	4.2 Analysis of relationships	
	4.3 Analysis of organizational principles	
5.0 Synthesis		
	5.1 Production of a unique communication	
	5.2 Production of a plan, or proposed set of operations	
	5.3 Derivation of a set of abstract relations	
6.0 Evaluation		
	6.1 Evaluation in terms of internal evidence	
	6.2 Judgments in terms of external criteria	

After the Bloom's Taxonomy has been presented many years ago, Anderson and Krathwohl (2001) decided to revise it since they saw an anomaly in the taxonomy. The learning objectives were expressed by using a noun and a verb. e.g.: "The student will understand the foundations of IoT technology". By following the Bloom's Taxonomy, the noun, in this case "foundations of IoT", is the provided knowledge, while the verb dimension, in this case "understand", is provided through a sub-dimension of the knowledge dimension. Krathwohl (2002) argues that Bloom provides a unidimensional representation of a bi-dimensional concept. This leads to an anomaly of the representation. Anderson and Krathwohl (2001) separated therefore the noun and the verb in two different dimensions by creating a bi-dimensional taxonomy. They propose a taxonomy with two dimensions, the knowledge dimension and the cognitive process dimension, where the noun in a learning objective representing the knowledge dimension and the verb represents the cognitive process dimension, which will be explained in the following.

The Knowledge Dimension: The knowledge dimension describes what to teach (Anderson & Krathwohl, 2001). The authors agree that although it is recommended to follow principles of constructivism, and apply experiential teaching methods, where students actively participate in creating the learning unit, one of the goals of teaching and learning itself is in creating knowledge. The knowledge dimension describes what the teachers want to teach. It helps also in defining and thinking about teaching "in a wide variety of subject matters as well as different grade levels" (Anderson & Krathwohl, 2001). The three first categories of the knowledge dimension match with the original categories as defined by Bloom. However the authors extend these with a fourth dimension, the metacognitive dimension. This dimension defines ones knowledge about cognition. This knowledge dimension was not known in the time where Bloom defined his taxonomy, it has been however developed in the following years and is important to be considered while defining learning outcomes (Anderson & Krathwohl, 2001). A complete overview of the structure of the knowledge dimension for the Revised Bloom's Taxonomy is provided in Table 7.

Table 7: Structure of the Knowledge Dimension
(Source: Own Representation Based on Anderson and Krathwohl (2001))

A. Factual Knowledge – The basic elements that students must know to be acquainted with a discipline or solve problems in it.
Aa. Knowledge of terminology
Ab. Knowledge of specific details and elements
B. Conceptual Knowledge – The interrelationships among the basic elements within a larger structure that enable them to function together.
Ba. Knowledge of classifications and categories
Bb. Knowledge of principles and generalizations
Bc. Knowledge of theories, models, and structures
C. Procedural Knowledge – How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods.
Ca. Knowledge of subject-specific skills and algorithms
Cb. Knowledge of subject-specific techniques and methods
Cc. Knowledge of criteria for determining when to use appropriate procedures
D. Metacognitive Knowledge – Knowledge of cognition in general as well as awareness and knowledge of one's own cognition.
Da. Strategic knowledge
Db. Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge
Dc. Self-knowledge

The Cognitive Process Dimension: Two of the most important goals in education are to promote retention and transfer. While retention is the ability to remember the material, transfer describes the ability not only to remember but also to use the learned material and apply it in practice (Anderson & Krathwohl, 2001). A combination of both goals is important while defining learning objectives and designing learning courses. However while retention is easier to be included in learning, transfer is more difficult. Therefore the cognitive dimension of the revised taxonomy aims at focusing also on the transfer dimension. The first cognitive dimension focuses on retention and the five following on transfer (Anderson & Krathwohl, 2001).

The revised taxonomy includes six cognitive process categories and a total of 19 specific cognitive processes within these categories (Table 8). The categories have been renamed in comparison to Bloom's Taxonomy, to better serve the purpose of the cognitive process dimension. Similar to the original taxonomy the different categories differ in complexity, e.g. remember is less complex than understand, which is less complex than apply and so on. However the strict categories have been relaxed and the objectives can also overlap between the different dimensions in order to offer the teacher more flexibility in defining the objectives and applying them (Anderson & Krathwohl, 2001).

Table 8: Structure of the Cognitive Process
(Source: Own Representation Based on Anderson and Krathwohl (2001))

1.0 Remember – Retrieving relevant knowledge from long-term memory.	
	1.1 Recognizing
	1.2 Recalling
2.0 Understand – Determining the meaning of instructional messages, including oral, written, and graphic communication.	
	2.1 Interpreting
	2.2 Exemplifying
	2.3 Classifying
	2.4 Summarizing
	2.5 Inferring
	2.6 Comparing
	2.7 Explaining
3.0 Apply – Carrying out or using a procedure in a given situation.	
	3.1 Executing
	3.2 Implementing
4.0 Analyze – Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose.	
	4.1 Differentiating
	4.2 Organizing
	4.3 Attributing
5.0 Evaluate – Making judgments based on criteria and standards.	
	5.1 Checking
	5.2 Critiquing
6.0 Create – Putting elements together to form a novel, coherent whole or make an original product.	
	6.1 Generating
	6.2 Planning
	6.3 Producing

4.2.2.2 Design Thinking

For the detailed planning of the learning units that is the third step of the curriculum development approach as described in Chapter: 4.2.1.3 Phase 3: Detail Planning of the Learning Units, a design thinking approach was applied.

As suggested by Knigge et al. (2018) design thinking is recommended for curriculum development since it offers the possibilities to better understand the target group including instructors and students. It makes it possible to empathize with the students and lecturers as end users of the curriculum and develop a curriculum that is based on their desires. Design thinking offers an advantage since it considers the desirability as a human psychological factor, feasibility as a technical and procedural factor and viability as an economical factor (Grots & Pratschke, 2009). The method is also widely applied from different companies as Allianz, Audi, Ball Packaging Europe, Clariant, Deutsche Bank, FIFA, Haufe-Lexware, Merck, SAP, Swisscom, Telecom Austria Group, UBS or Washtec (Hoffmann, Lennerts, Schmitz, Stölzle, & Uebernickel, 2016) as it helps in being more innovative and developing better end products. It is a customer oriented and iterative process that delivers solutions for complicated issues. Design thinking has proven to be also usable for developing curricula, especially in technical areas as e.g. in the case of developing a curricula for Industry 4.0 (Knigge et al., 2018). It involves the end users and helps therefore in delivering a more desirable curriculum. Therefore, at this stage of the curriculum development, design thinking was applied together with the project team (see 1.5 Project and Dissertation Context).

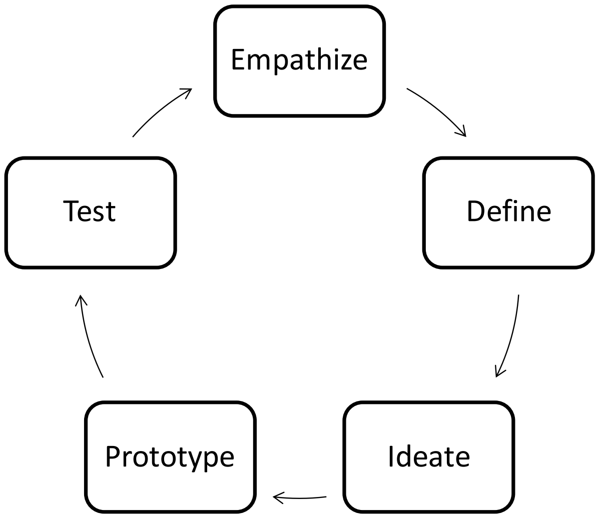

Figure 14: Design Thinking Phases for Curriculum Development.
(Source: (Knigge, Prifti, & Krcmar, 2018))

There are many different design thinking approaches, with different numbers of steps. In the presented context, a design thinking approach that includes five steps as: Empathize, Define, Ideate, Prototype and Test (Figure 14) is applied.

The design thinking phase of this work was conducted from a group of researchers working in the curriculum development project (see 1.5 Project and Dissertation Context).

4.2.2.2.1 Empathize

This step of the design thinking process includes interaction with the end users. The goal is to empathize with the users and understand their problem in order to be able to develop solution patterns afterwards. In the first step the team defines a challenge to solve and tries to understand it. After that the design thinking team can define interview questions and conduct interviews with potential users in order to gather input on how to solve the challenge (Knigge et al., 2018).

During the curriculum development, competencies for Industry 4.0 were defined. Furthermore the challenge was to "Define a curriculum for the digital transformation towards Industry 4.0 for CS, IS and Engineers". Based on this, a team of five researchers gathered and discussed about the content of possible modules and how they could be developed. Furthermore we discussed with lecturers and students as well as professors to understand what kind of curriculum they would wish. At the end of this step we gathered many ideas how the Industry 4.0 curriculum could look like and what kind of modules and learning units we should include (Knigge et al., 2018).

4.2.2.2.2 Define

In the define phase the team can structure the information gathered during the empathize phase. In this phase the team should put itself in the position of the user and try to think from the user perspective. To structure the results from the interviews, the building of personas is recommended (O'Grady & O'Grady, 2009). A persona is an aggregated user profile that helps in better understand the user and put one's self in the user's perspective.

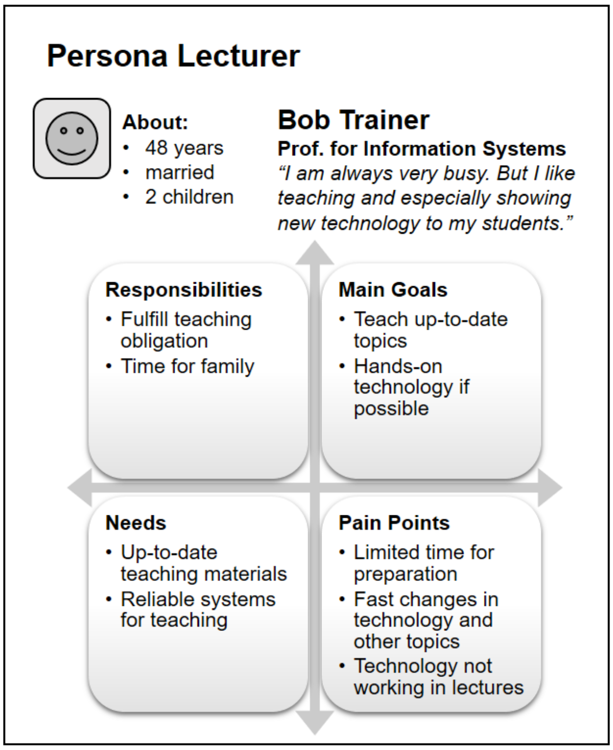

Figure 15: Persona

(Source: Knigge et al. (2018))

Based on that, we developed some personas that were afterwards used to understand the profiles of the curriculum users. One of the developed personas is presented in Figure 15. It describes one key lecturer that could be the standard user of the developed curriculum.

The personas helped us in better understanding the end users of the curriculum and be able to put ourselves in the position of the lecturer (Knigge et al., 2018).

4.2.2.2.3 Ideate

In this phase of the design thinking process, different ideas for the developed personas should be developed. One of the methods that can be applied here is brainstorming. Through brainstorming the team can develop different ideas and possible solutions. Based on the results of the brainstorming a clustering of the results should be defined (Knigge et al., 2018).

We applied brainstorming to generate ideas about how the general structure of our curriculum could look like. In our discussion we built different clusters after the discussion, including: curriculum structure, content, learning method, delivery method (Knigge et al., 2018).

After the clustering of the brainstormed ideas we choose some of the ideas that were afterwards used to develop the prototype as described below.

4.2.2.2.4 Prototype

In the prototype phase artefacts are generated that can be taken into consideration as potential solutions. The principle behind it is “Make it tangible”. It helps in generating tangibles prototypes that can be shown afterwards to the user in order to discuss and gather feedback. There are two types of prototypes low fidelity and how fidelity. Schlachtbauer, Schermann, and Krcmar (2013) showed that low-fidelity prototypes can improve the creativity of the team. While high fidelity are used for going more into detail.

In our team at this step we gathered information for defining the overall structure of the curriculum and came up with a first curriculum structure prototype that is shown in Figure 16.

The first structure prototype of the curriculum included 19 modules in five clusters. Each module could have more learning units depending on the topic (Knigge et al., 2018).

4.2.2.2.5 Test

The last phase of one cycle is the testing phase. In this phase the design thinking team goes again in contact with the customers/users and gets feedback. The developed prototype is used and shown to the users in order to make the solution more visible and tangible (Knigge et al., 2018).

In our project we conducted a whole day workshop for the evaluation of the prototype. The participants of the workshop were nine research associates and three professors with several years of experience in teaching and curriculum development. We presented the results and discussed them in order to achieve improvements (Knigge et al., 2018). At the end we reached an improved version of the structure which is presented at 4.4 **Curriculum Overview**.

After the structure was defined, the learning objectives, learning content and learning methods were defined for each of the defined modules.

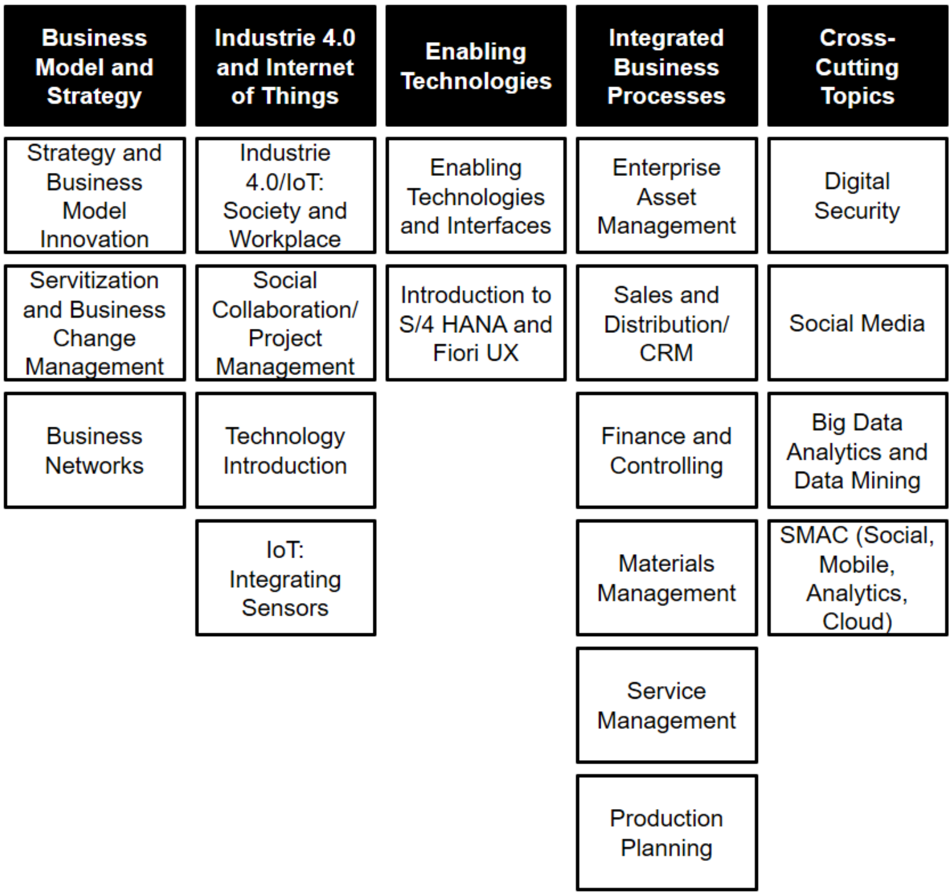

Figure 16: Curriculum Idea
(Source: Knigge et al. (2018))

4.3 Teaching Methods

As described in Chapter 4.2.1.4 Phase 4: Learning Unit Content, it is important to include various interactive learning methods while developing a curriculum. In the developed curriculum several methods and theories were applied which are described in this section.

Experiential Learning: Experiential learning was first introduced by Kolb (1984) and is based on six propositions as: "

1. *Learning is best conceived as a process, not in terms of outcomes*. - In higher education the focus should lie on engaging students in the process and give them feedback on their learning efforts.
2. *All learning is relearning*. - The learning process should include the possibility to examine, test and combine student ideas with new one, for a better understanding about the topic.

3. *Learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world*. - The learning process is driven through differences, conflict and discussions.
4. *Learning is a holistic process of adaptation to the world*. - Learning goes beyond cognition by including thinking, feeling, perceiving, and behaving.
5. *Learning results from synergetic transactions between the person and the environment*. - Learning occurs through a synergetic process where new experiences are integrated in existing concepts and existing concepts are accommodated to new experiences.
6. *Learning is the process of creating knowledge*. – Through experiences the learner creates personal knowledge" (Kolb & Kolb, 2008; Kolb, 2005)

In this theory learning is defined as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience". Kolb (2005) states that learning is a cycle consisting of four phases: concrete experience (CE), which persists in performing specific tasks and hand-on exercises; reflective observation (RE), which consists of a synthesis and reflection of the experience in order to understand the theories and concepts of a certain discipline, abstract conceptualization (AC), which includes the application of the acquired knowledge and active experimentation (AE), which allows in taking the absorbed knowledge one step further and experimenting in different practical setting (Figure 17). The two dialectically related modes CE and AC consist in grasping experience and the other two RO and AE in transforming experience (Kolb, 2005).

In experiential learning the learner takes a central role (e.g., (Andresen, Boud, & Cohen, 1997; Kolb, 2005) and it promotes crucial behavioral competency and abilities. Therefore, elements of experiential learning were applied in various aspects of the curriculum, in order to help in the learning of behavioral experiences.

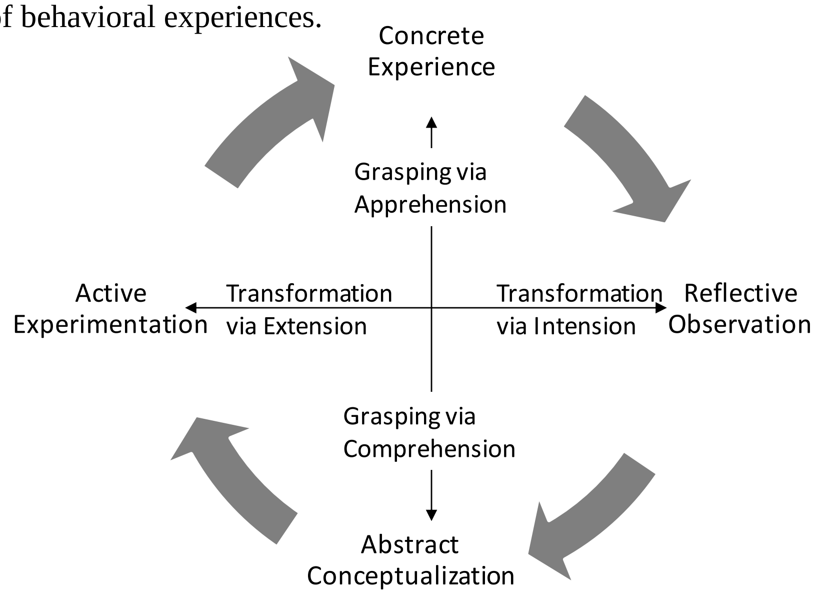

Figure 17: Experiential Learning
(Source: Own Representation Based on Kolb and Kolb (2008))

Teaching Case: Teaching cases, also called case based teaching present the students with concrete problems. The students are required to discuss the situation and find, identify and justify appropriate solutions (Studer, 2002). The goal is to motivate students to work with one another and to bring a discussion about the topic at hand (Wasserman, 1994). The case offers a foundation, with which the class can unfold in complicated interactions and discussions about the business situations provided by the teaching case (Wasserman, 1994).

The method builds on existing knowledge and applies it on a concrete context (Studer, 2002). Nevertheless, case-based teaching helps in the constructivist learning process while learning through experience. The student can build new knowledge based on the experience and it provides the acquisition of a deep understanding of complex issues (Antonia, 2002). It is the connection of knowledge with various methods that provide analytical as well as synthetic thinking (Boss-Ostendorf & Senft, 2010). It also aims to strengthen the vocabulary and terminology of a topic or subject (Savery, 2006) and helps in promoting the cognitive dissonance to exercise critical thinking skills (Wasserman, 1994). In accordance to that, case-based teaching combines theoretical and practical understanding of the topic (Prince & Felder, 2006).

The goals of case based teaching are to show a practical relevance and give students the possibility to gain a better understanding of making decisions and finding solutions (Antonia, 2002; Studer, 2002). It can be conducted in groups and thereby it leads to communication and collaboration skills (Savery, 2006).

“The case method is a powerful approach to teaching and learning business subjects. Its main advantage is that it is a “question-oriented”, as opposed to solution-based, approach to teaching and learning. It allows students to participate in “real-life” decision making processes by first identifying the major “question” in the case before formulating appropriate solutions.”(Farhoomand, 2014)

Therefore principles and aspects of case based teaching were applied in the curriculum, in order to promote the behavioral skills mentioned above as well as offer a different method that helps the students in positioning themselves to a real life situation and is more interactive and fun.

Design Thinking: Design thinking was applied during the development of the curriculum. However this is one of the aspects to apply design thinking. The literature shows that design thinking or design based learning is a method applied in the learning context too. Faste, Roth, and Wilde (1993) applied the method in Engineering education. It helps the students in developing innovative ideas, and be able to concretize them in form of prototypes. It offers benefits in promoting creativity, teamwork, communication etc. More than that it can be applied in different situations and has proven to offer a method that is fun for the students. Uebernickel and Brenner (2016) describe four perspectives that are connected to design thinking:

- Design thinking puts the customer at the center of the solution. Every idea and solution is developed by focusing on the customer (Brown, 2008). In this way it offers the possibility to develop customer related competencies and better understand the customer.

- It is applied to solve complex problems and helps in building clarity on the problem itself. Many authors describe the application of design thinking for so called ill-defined problems (Buchanan, 1992; Churchman, 1967). In this way, by including the method in education it helps the students in building competencies with regards to complexity, problem solving etc.
- Unconventional thinking is the ability to think out of the box and bring new and unconventional ideas for solving usual problems (Runco & Acar, 2012). Design thinking supports this kind of thinking and helps in this way in problem solving and creativity by supporting the ability to think and act independently.
- It is an iterative approach that repeats the phases many times and improves the solution until a final solution is achieved (Schindlholzer, Uebernickel, & Brenner, 2011). Applied in education this method offers the possibility of reflection and can be used as a basis for discussion and optimization.

Based on these advantages, the design thinking approach is included as a learning method in the curriculum as it builds a basis for developing behavioral competencies.

Blended Learning: The developed curriculum offers a combination of own developed learning content as well as online available MOOCs from 3rd parties. Combining classroom and online learning is defined as blended learning (Al-Qahtani & Higgins, 2013). The aim of these kind of e-learning format are: "

1. pedagogical richness,
2. access to knowledge,
3. social interaction,
4. personal agency,
5. cost effectiveness,
6. ease of revision';" (Osguthorpe & Graham, 2003)

Through additional readings, self-assessments, exercises and online discussions, it offers time flexibility (Al-Qahtani & Higgins, 2013). These lead to the possibility of a self-paced learning (Kigozi, Ekenberg, Hansson, Tusubira, & Danielson, 2008). Moreover, it faces the challenge to meet different learning styles and students get the opportunity to learn on their own (Ho, Lu, & Thurmaier, 2006). Ho et al. (2006) mentioned that through blended learning lower dropout rates can be achieved.

In this way the method offers the possibility to promote competencies as lifelong learning, undependable working etc. The method is not directly offered in the curriculum, however it is presented in the learning journeys, since the lecturers and students can combine the developed theory slides and practical parts with the provided MOOCs that are available online.

4.4 Curriculum Overview

4.4.1 General

The digital economy changes the rules of business. New digital technologies arise in every industry sector by transforming processes and whole business models. The businesses as we know them change with the help of technological developments as mobile, social, analytics, cloud, platforms, IoT or Industry 4.0. Businesses act in agile and competitive environments, where they tend to differentiate themselves through personalized products and services that are becoming the most popular strategies of the digital era. Servitization is the term used for the transformation in which the industries and manufacturers offer services connected to their products.

Due to this trends and the changing environment many businesses are facing difficulties in keeping up with the transformation and adapting in an environment where the rules of business have changed.

To be able to succeed in the digital transformation, a holistic view of business strategy with the impact that digital technologies have on customers, competition, big data innovation and value creation is needed. For being able to transform to an Industry 4.0 company, a company faces many challenges that are addressed by this curriculum. The curriculum shows how a traditional manufacturing company can adapt in the digital age, by focusing on the model company Global Bike Inc. (GBI).

GBI is a model company used for many years in the teaching of integrated business processes in the area of SAP education (Magal, Weidner, & Word, 2016). It has been a traditional bike manufacturer producing touring and off road bike for many years. Due to the digital transformation, GBI faces challenges and is forced to follow a transformation in a product service provider, who rents IoT city bikes (Prifti, Knigge, Löffler, & Krcmar, 2018). A detailed description of the transformation of GBI is provided in Section 4.4.3 The Global Bike Story.

The goal of the curriculum is to describe a step by step transformation of the GBI company from a traditional bike manufacturer to a product service provider. The curriculum aims the target group of this thesis that includes IS; CS and Engineering students.

By building on an existing model company, it gives the lecturers the possibility to use the existing knowledge and expand it further. Furthermore it helps to better understand the transformation and it applies the constructivist approach of teaching the content based on a concrete example. The curriculum is based on the competencies built in the first part of this thesis and aims in teaching them in the single units.

The curriculum covers many topics and is not meant to be conducted from a lecturer completely through a whole semester. The curriculum delivers learning content for the I 4.0. Each lecturer can choose the own focus and mix and match the content depending on their demands and needs. In the following part a description of the curriculum is provided.

4.4.2 Learning Objectives

Based on the competencies derived in the first part of the thesis as well as the overall goal described above the general learning goals for the curriculum are defined. These are based on the Revised Blooms Taxonomy (Anderson & Krathwohl, 2001) and combine both dimensions of learning objectives. The learning objectives for the curriculum are described below. Table 9 presents which dimensions each learning objective covers.

After completing this course the students will:

LO01: remember the main terminology and aspects of the digital transformation towards Industry 4.0
LO02: understand the basic technological aspects of Industry 4.0
LO03: apply methods and tools to extract information for Industry 4.0
LO04: analyze the impact of Industry 4.0 on the economical, sociological, organizational and technical aspect
LO05: evaluate the Industry 4.0 scenarios and aspects with regards to their value for a company
LO06: create own solutions for different aspects in the context of Industry 4.0

Table 9: Learning Objectives
(Source: Own Representation Based on Anderson and Krathwohl (2001))

	The Cognitive Process Dimension					
The Knowledge Dimension	1.Remember	2.Understand	3.Apply	4.Analyze	5.Evaluate	6.Create
A. Factual Knowledge	LO01					
B. Conceptual Knowledge		LO02		LO04		
C. Procedural Knowledge			LO03			
D. Metacognitive Knowledge					LO05	LO06

4.4.3 The Global Bike Story

The curriculum is based on an umbrella teaching case and an overall story that covers all the modules and is taken every time into consideration for the single modules by going deeper into a specific aspect. Below the Global Bike story is presented.

Global Bike Group started at 2001 as a combination of two companies: the US company Frankenstein bikes and the German company Heidelberg composites. The company is built of two subsidiaries the American subsidiary with basis in Dallas Miami and San Diego and the German subsidiary based in Heidelberg and Hamburg. The company is focused on a small niche market of distributers and other retailers by producing and selling mountain bikes and running bikes and have been a market leader in the sector for years (Magal et al., 2016). The company has always been focused on technology and their products were leading in technology for years. The company is managed from two CEOs: John Davis from USA, who is mainly responsible for marketing, sales, finance and all the economic aspects of the company and Peter Schwarz, responsible for the technological aspects and for building the bikes (Magal et al., 2016).

By following the actual trends of IoT, digitalization, sensors and automation, the company decided in the year 2015 to introduce a new product: the IoT bike. An electric bike equipped with sensors that can calculate different outputs based on the values of the sensors. The CEOs hopped to be able to give a new face to the company through the new product. The company founded therefore a new subsidiary responsible for producing and selling the IoT bikes (Figure 18).

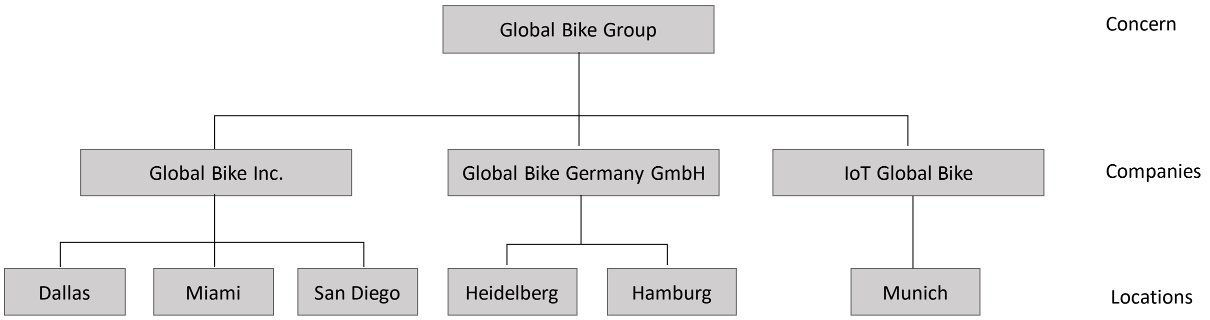

Figure 18: Structure of Global Bike Company
(Source Prifti, Knigge, Kienegger, et al. (2017))

The IoT bikes however did not succeed and the company was facing difficulties by standing in a position where they had invested on a new product and could not cover the costs anymore. In this situation the new Chief Digitalization Officer, decided to transform the business model of the company to a product service provider (Figure 20) – the Global Bike Sharing (GBS) was born. In this way the company could rent the IoT bikes as city bikes for tourists or further special groups of interest. The bike was able to create inputs and outputs and would offer a value to the users (**Fehler! Verweisquelle konnte nicht gefunden werden.**) and the possibility to develop a complete new business model and new scenarios. The company would transform from a classical B2B manufacturer to a B2C product service provider.

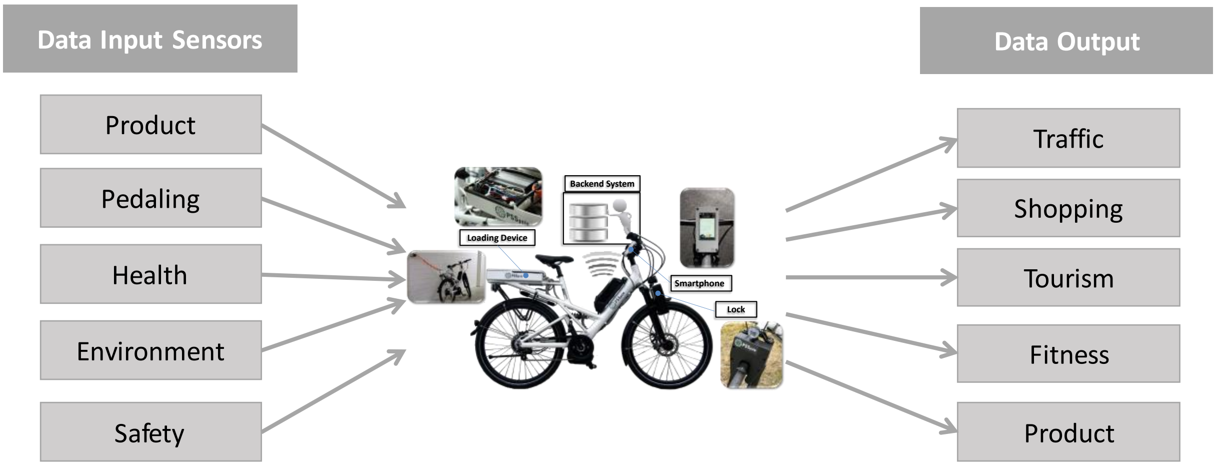

Figure 19: The IoT Bike
(Source: Prifti, Knigge, Löffler, and Banova (2017))

Based on this story all the modules and learning units of the curriculum are built. This offers the possibility to the students also to build a certain connection to the company, and accompany the company through the different steps of the transformation. The story also keeps the students interested and engaged since they want to follow the steps and want to know more about the company.

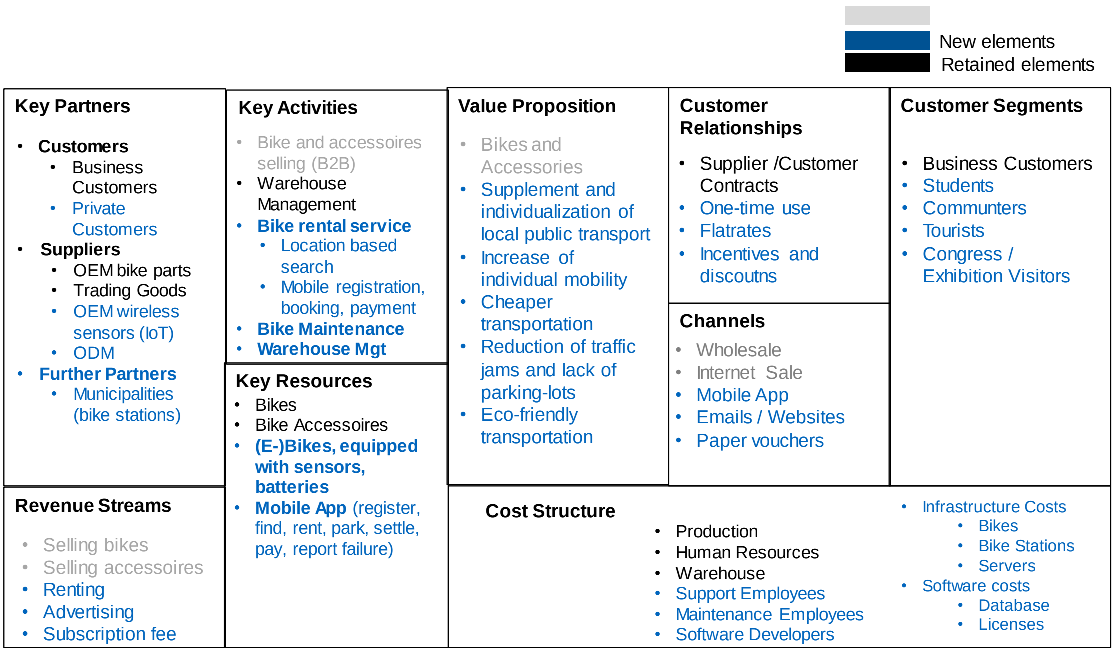

Figure 20: The Business Model of GBS
(Source: Prifti, Knigge, Löffler, and Banova (2017))

4.4.4 Overall Structure

Learning Units were developed that cover the main aspects of the digital transformation of Global Bike – from rethinking the business strategy and value proposition to exploiting the potential of the IoT. The curriculum includes 19 modules. Each module includes different learning units with theory slides, case studies and exercises as well as links to MOOCs available online and further available curricula for deepening into the topics. An overview of the modules is provided in Figure 21.

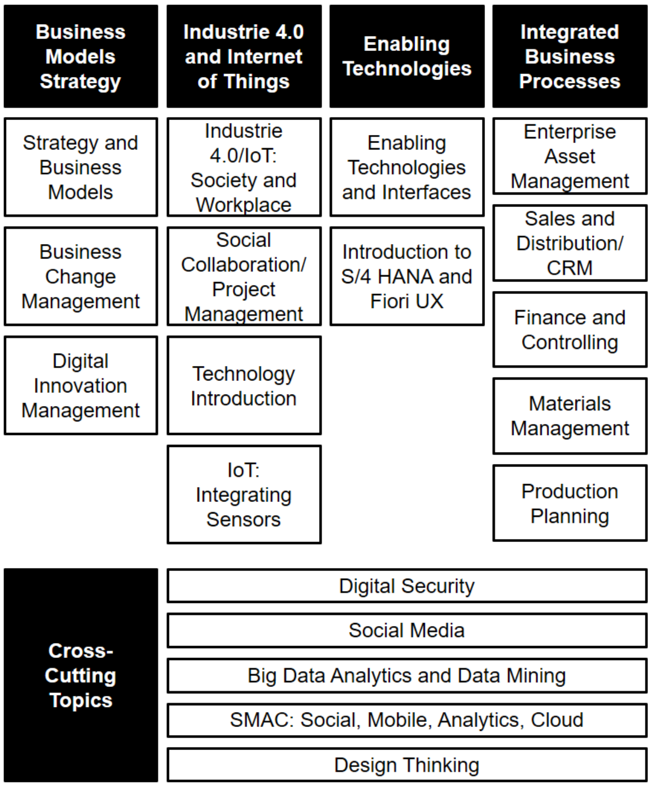

Figure 21: Modules of the Curriculum
(Source: Prifti, Knigge, Löffler, and Banova (2017))

The digital transformation of Global Bike from a traditional manufacturer to a Product-Service-System (PSS) provider comprises the following phases:

1) **Business Strategy and Value Proposition**: The first three curriculum's modules address the business strategy transformation of Global Bike from a manufacturer in a B2B market to a product service provider in the B2C market. For this, the adaptation of the main business strategy elements, according to established business change management principles, are described. An As-Is and To-Be comparison of the "old" and the "new" business strategy offer a vivid example of business strategy transformation as part of the servitization process. The digital innovation management is a further part that completes the rethinking of the strategy and delivery of a new, innovative service.

Competencies for the digital transformation: These section promotes the following competencies for the digital transformation: Leadership Skills, Presentation and Communication Ability, Decision Making, Business Process Management, Business Change Management, Creativity, Critical Thinking, Change Management, Business Strategy, Managing Complexity, Project Management, Business Model Understanding, Entrepreneurship, Collaborating with Others, Communicating with People, Compromising, Creating Business Networks, Maintaining Customer Relationships, Negotiating, Problem Solving

2) **Industry 4.0 and the Internet of Things**: This part of the curriculum includes four modules regarding the adoption of Industry 4.0 which comprises the close connection between IT and production technologies to offer new kind of products. Important aspects of Industry 4.0 are the IoT, smart factories, cyber physical and embedded systems. A definition and a general overview of Industry 4.0 and the IoT and their influences on society and workplaces are provided. Afterwards, further impacts on the model company Global Bike are considered. These comprise collaboration and project management, technology enhancements in general and the integration of sensors in particular, and the resulting requirements regarding the analysis of different kinds of data. Effects on the business model, business processes and the products and services are considered. As an example for IoT and cyber physical systems, gathering sensor data from bikes enables new processes, such as reactive and predictive bike maintenance (e.g., real-time monitoring and avoiding unexpected errors), real-time material supply (e.g., materials for replacement), and pricing (e.g., more effective way the provider charges its customers).

   Competencies for the digital transformation: These section promotes the following competencies for the digital transformation: Extract Business Value from Social Media, Service Orientation/ Product Service Offerings, Network Security, IT Architectures, Machine Learning, System Development, Integrating Heterogeneous Technologies, Mobile Technologies, Predictive Maintenance, , Modelling and Programming, Big Data/Data Analysis and Interpretation, Cloud Computing /Architectures, In-Memory DBs, Statistics, Data Security, Respecting Ethics, Targeted/Technical Communication, IT and Technology Affinity

3) **Enabling Technologies for the Digital Transformation:** The next two learning modules discuss the enabling technologies for the digital transformation of Global Bike. On the one hand, these are related to the servitization of Global Bike and its transformation to a PSS provider. On the other hand, the enabling technologies are related to the implementation of IoT as an integral part of the digital business processes of Global Bike. The integration of the reimagined Global Bike business processes is enabled by the new SAP Business Suite S/4 HANA.

   Competencies for the digital transformation: These section promotes the following competencies for the digital transformation: Collaborating with Others, Communicating with People, Targeted/Technical Communication, Literacy, Applying Expertise and Technology, IT and Technology Affinity, Service Orientation/ Product Service Offerings, Business Process Management, Business Change Management, Understand and

Coordinate Workflows, Integrating Heterogeneous Technologies, Mobile Technologies, Cloud Computing /Architectures

4) **Integrated Business Processes:** In the next five learning modules the transformed digital business processes of Global Bike are introduced, using the example of S/4HANA Enterprise Management. For each business process, the integration of sensor data, mobile technology, cloud and analytics are discussed. The main focus lies in showing the business process transformations related to the transition of Global Bike to a PSS provider by exploiting the potentials of digital technologies. The biggest change occurs in the sales process where the classical sales process is transformed in a renting process also supported through a mobile app.

   Competencies for the digital transformation: These section promotes the following competencies for the digital transformation: Targeted/Technical Communication, IT and Technology Affinity, Economics, Service Orientation/Product Service Offerings, Business Process Management, Business Change Management, Understand and Coordinate Workflows, Customer Orientation, Customer Relationship Management

5) **Raising Awareness about Digital Security:** This learning unit deals with legal and security aspects in a digitized environment. On the one hand, it takes a look at questions like who is the owner of which data and which kinds of analytics and processing are allowed. On the other hand, with the increasing number of machines and devices connected to the internet, data is highly exposed to attacks: e.g., theft, deletion, and manipulation. An overview of common and new kinds of risk exposures and countermeasures is given.

   Competencies for the digital transformation: These section promotes the following competencies for the digital transformation: Respecting Ethics, Network Security, Data Security, Legislation Awareness, Safety Awareness, Individual Responsibility

6) **Integrating Social Media and Advanced Analytics for Richer Customer Insight:** The concept of PSS allows companies to offer customer focused products by matching classical product concepts with service concepts. Gaining knowledge about customers' sentiments plays therefore a central role for the PSS provider Global Bike. While traditional means of gathering this information, e.g. by conducting surveys, are time consuming and suffer under low response rates, the analysis of data from social networks like Twitter and Facebook offers new opportunities to extract customer sentiments. In this learning unit, the analysis of data from social media are considered as a means for Global Bike to react to their customers' sentiments.

   Competencies for the digital transformation: These section promotes the following competencies for the digital transformation: Respecting Ethics, Creating Business Networks, Economics, Extract Business Value from Social Media, Big Data/Data Analysis and Interpretation, Cloud Computing /Architectures, In-Memory DBs, Statistics, Problem Solving, Optimization, Analytical Skills

7) **The Role of Big Data Analytics in the Industry 4.0 Environment:** This learning unit describes the role of big data analytics for the new GBS company. Besides conventional

business reporting, an Industry 4.0 environment offers additional sources and kinds of data to be used for business analytics. New products equipped with sensors, generate huge amounts of data which have to be processed, like various signals such as vibration, air pressure, etc. In addition, historical data can be harvested with modern means of data mining. Moreover, the combination of transaction and social media data enables new insights into consumer sentiments. The processing of big data into valuable information is the key of sustainable innovation in the digital economy.

Competencies for the digital transformation: These section promotes the following competencies for the digital transformation: Big Data/Data Analysis and Interpretation, Cloud Computing /Architectures, In-Memory DBs, Statistics, Problem Solving, Optimization, Analytical Skills, network Security, Data Security

8) **Actual trends: SMAC:** SMAC stands for social-mobile-analytics-cloud and are considered as trends having a big role in the digital transformation. In this crosscutting section it is analyzed how the trends influence the company and can be addressed from a strategic and technical point of view.

   Competencies for the digital transformation: These section promotes the following competencies for the digital transformation: Targeted/Technical Communication, IT and Technology Affinity, Extract Business Value from Social Media

9) **Innovating through Design Thinking:** Design Thinking is an approach applied by many companies in the innovation process. This method is applied also in teaching, mostly in the education of technical oriented students and Engineers, CS specialists and IS specialists in order to help them develop innovative ideas and products. This method, is presented in a single unit and can be applied for answering different questions at different modules.

   Competencies for the digital transformation: These section promotes the following competencies for the digital transformation: Teamwork, Collaborating with Others, Communicating with People, Problem Solving, Optimization, Analytical Skills Innovating, Creativity, Critical Thinking, Customer Orientation, Work in Interdisciplinary Environments, Intercultural Competency, Flexibility, Adaptability and Ability to Change Mind-set

For each section of the curriculum the single modules and their content description are provided in Table 10.

Table 10: Curriculum Content
(Source: Own Representation)

Section 1: Business Model and Strategy	
Module 1.1: Strategy and Business Model Innovation	
Learning Objectives	• understand the fundamentals of business strategies and business models • understand the innovation process • understand the importance of business models and business strategies in the digital transformation • understand the impact of digitalization on business models and business strategy • understand the role of services in the business development • use known frameworks for business modelling and strategy description • evaluate existing business models and create new business models
Content	**Learning Unit 1.1.1: Strategy and Business Model Innovation** - Introduction Slides - Exercise - Case Study **Learning Unit 1.1.2: e3 Value** - Introduction Slides - Case Study
Software	No software required.
Module 1.2: Business Change Management	
Learning Objectives	• understand the fundamentals of business change management • understand the triggers for business change • understand the challenges for business change management in the digital transformation • understand the role of business change management • understand the critical tasks for implementing business change • understand the business change management roadmap in the digital transformation

Content	**Learning Unit 1.2.1: Business Change Management** - Introduction Slides - Exercise - Case Study
Software	No software required.
Module 1.3: Digital Innovation Management	
Learning Objectives	• understand the fundamentals of digital innovation management • understand the digital innovation process • understand the specifics of the digital innovation for the digital transformation • understand the typologies and determinants for innovation • understand the adopter categories for innovation • understand the difference between open and closed innovation
Content	**Learning Unit 1.3.1: Digital Innovation Management** - Introduction Slides - Exercise - Case Study
Software	No software required.
Note: Through the exercises and case studies provided in these three modules that can be conducted as a teamwork, we provide an interactive and experiential learning content. The students have the chance to develop their own ideas, research about the topics and come up with innovative results that they can present in class. These exercises aim in promoting behavioral competences as teamwork, collaboration, communication, presentation ability, problem solving, creativity etc. There is no right or wrong solution in these exercises. Students are required to generate their own content and learn while doing it. Therefore, we do not provide a sample solution for the most of the content.	

Section 2: Industry 4.0 and the Internet of Things	
Module 2.1: Industry 4.0: Society and Workplace	
Learning Objectives	• understand the main changes caused by Industry 4.0 • understand the impacts of the changes caused by Industry 4.0 on society and everyday lives • understand the impacts of the changes caused by Industry 4.0 on workplaces • are able to apply their knowledge in discussing advantages and disadvantages that come with Industry 4.0
Content	**Learning Unit 2.1.1: Industry 4.0: Society and Workplace** - Introduction Slides
Software	No software required.
Module 2.2: Social Collaboration and Project Management	
Learning Objectives	• understand the importance of collaboration in Indutry 4.0 • are able to apply their knowledge and discuss which collaboration forms and tools may be helpful in a given setting • understand the challenges of project management • understand the most common variants of project management • are able to apply methods of project management
Content	**Learning Unit 2.2.1: Introduction to Project Management** - Introduction Slides **Learning Unit 2.2.2: Introduction to Social Collaboration** - Introduction Slides
Software	No software required.

Module 2.3: Technology Introduction	
Learning Objectives	• understand the fundamentals of the digital transformation • understand the megatrends that arise through digital transformation • understand the fundamentals of Industry 4.0 • understand the fundamentals of the Internet of Things
Content	**Learning Unit 2.3.1: Technology Introduction** - Introduction Slides
Software	No software required.
Module 2.4: IoT – Integrating Sensors	
Learning Objectives	• understand fundamentals of sensor technology • understand the relevance of sensors for IoT • understand the challenges of sensor usage • understand main applications of sensor technology • understand business scenarios and IoT products enabled by sensor technology
Content	**Learning Unit 2.4.1: IoT – Introduction** - Introduction Slides **Learning Unit 2.4.2: IoT – Data Collection** - Introduction Slides - Case Study **Learning Unit 2.4.3: IoT – Data Analytics & Reporting** - Introduction Slides - Case Study **Learning Unit 2.4.4: IoT – Maschine Learning** - Introduction Slides - Case Study
Software	SAP HANA
Section 3: Enabling Technologies	
Module 3.1: Introduction to Enabling Technologies and Interfaces	

Learning Objectives	• describe software and hardware innovations • understand technologies enabling the digital transformation and servitization of a traditional business • understand the integration of the different enabling technologies • evaluate the resulting business value for companies
Content	**Learning Unit 3.1.1: Introduction to Enabling Technologies and Interfaces** - Introduction Slides
Software	No software required.
Module 3.2: Introduction to S/4HANA and Fiori UX	
Learning Objectives	• describe SAP S/4HANA and its innovations • understand how S/4HANA enables the digital transformation of enterprises • understand how SAP Fiori provides a new user experience in information systems • compare the new Business Suite S/4HANA to the Business Suite powered by HANA
Content	**Learning Unit 3.2.1: Introduction to S/4HANA and Fiori UX** - Introduction Slides - Video - Case Study
Software	SAP S/4 HANA SAP Fiori 2.0

Module 4.1: Sales and Distribution	
Learning Objectives	• describe all steps of the sales and distribution process of a Product Service System (PSS) provider • understand process innovation and re-design • explain and analyze the impact of digitalization on these processes • understand how the products and processes of GBI are transforming • understand the integration of sales and distribution with further processes in the company
Content	**Learning Unit 4.1.1: Sales and Distribution** - Introduction Slides

	- Case Study
Software	SAP S/4 HANA SAP Fiori 2.0
Section 4: Integrated Business Processes	
Module 4.2: Materials Management	
Learning Objectives	• describe all steps of materials procurement and management processes • understand process innovation and re-design • explain and analyze the impact of digitalization on these processes • understand how the products and processes of GBI are transforming • understand the integration of materials management with further processes in the company
Content	**Learning Unit 4.2.1: Materials Management** - Introduction Slides - Case Study
Software	SAP S/4 HANA SAP Fiori 2.0
Module 4.3: Finance and Controlling	
Learning Objectives	• describe Finance and Controlling of a Product Service System (PSS) provider • understand process innovation and re-design • explain and analyze the impact of digitalization on these processes • understand how the products and processes of GBI are transforming • understand the integration of Finance and Controlling with further processes in the company
Content	**Learning Unit 4.3.1: Finance and Controlling** - Introduction Slides - Case Study
Software	SAP S/4 HANA SAP Fiori 2.0
Module 4.4: Enterprise Asset Management	

Learning Objectives	• describe the Enterprise Asset Management (EAM) of a Product Service System (PSS) provider • understand process innovation and re-design • explain and analyze the impact of digitalization on these processes • understand how the products and processes of GBI are transforming • understand the integration of EAM with further processes in the company
Content	**Learning Unit 4.4.1: Enterprise Asset Management** - Introduction Slides - Case Study
Software	SAP S/4 HANA SAP Fiori 2.0
Module 4.5: Production Planning	
Learning Objectives	• understand and describe the production planning process of a Product Service System provider • explain and analyze the impact of digitalization on the production planning process • analyze and evaluate *Make* or *Buy* decisions • understand the integration of production planning with further processes in the company
Content	**Learning Unit 4.5.1: Production Planning** - Introduction Slides - Case Study
Software	SAP S/4 HANA SAP GUI 7.5
Section 5: Digital Security	
Module 5.1: Digital Security	
Learning Objectives	• understand the main security threats in an Industry 4.0 environment • are able to recognize security threats in a connected environment
Content	**Learning Unit 5.1.1: Digital Security** - Introduction Slides
Software	No software required.

Section 6: Social Media	
Module 6.1: Social Media	
Learning Objectives	• understand how social media can add business value • understand how their private behavior in social media might affect their professional lives
Content	**Learning Unit 6.1.1: Social Media** - Introduction Slides - Case Study
Software	No software required.

Section 7: Smart Data Analytics	
Module 7.1: Smart Data Analytics	
Learning Objectives	• understand the meaning and the value of smart data analysis • understand the most common kinds of algorithms for smart data analysis • are able to apply their knowledge and built their own smart data analysis • are able to apply their knowledge and extract business value from smart data
Content	**Learning Unit 7.1.1: Smart Data Analytics** - Introduction Slides - Case Study - Video
Software	SAP HANA

Section 8: SMAC	
Module 8.1: SMAC	
Learning Objectives	• understand the concept of SMAC and the underlying concepts • understand the main aspects of the component "Social" • understand the main aspects of the component "Media" • understand the main aspects of the component "Analyt-ics" • understand the main aspects of the component "Cloud" • are able to apply their knowledge regarding the four components to understand the impact of SMAC as a whole

Content	**Learning Unit 8.1.1: SMAC** - Introduction Slides
Software	No software required.
Section 9: Design Thinking	
Module 9.1: Design Thinking	
Learning Objectives	• Understand and apply design thinking for discussion and idea generation • Work in teams and present the results of the work
Software	No software required.
Note: This module provides a slide deck that can be used as a basis for a design-thinking workshop. The slide deck also provides two challenges as an example. However, the main goal is to use it in order to develop solutions for various challenges, which could be defined by the lecturers or the students themselves. If you wish you can also use one of the challenges provided in the Section 1 of the curriculum, either in the exercises or in the case studies in order to conduct a design thinking workshop. Design thinking offers a state of the art approach that is user centric and offers the possibility to work in team and develop creative solutions to complex problems. It can be applied for strategic as well as technology related challenges. It offers a good base to be applied in teaching since it promotes many behavioral competences and at the same time offers an interactive approach that is usually welcomed by the students.	

4.4.5 Accompanying Measures

In order to offer the possibility to flexibly access the curriculum content, an HTML application was developed. It offers an interactive delivery method and the possibility to browse through the content and to better and faster earn an overview on the whole curriculum. Furthermore the HTML application offers the possibility to include additional tools as accompanying measures to the curriculum.

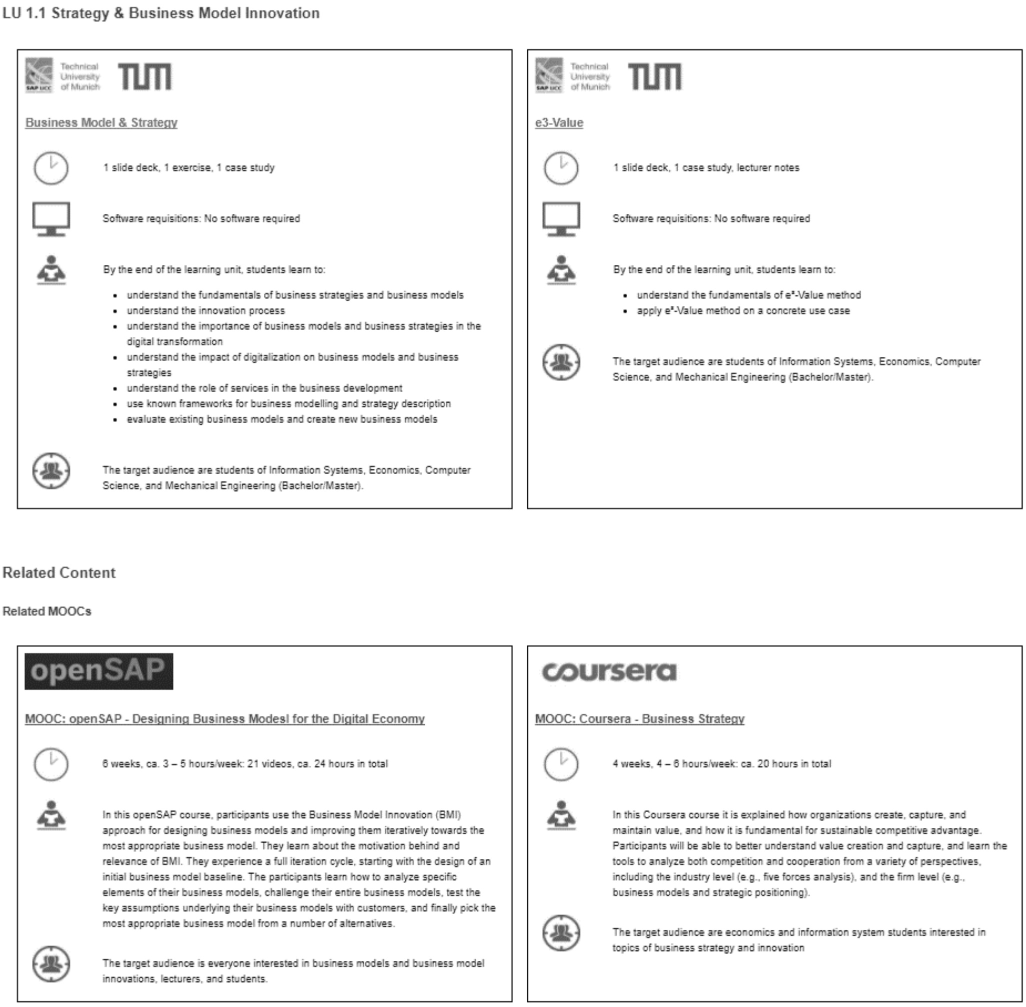

Figure 22: Module Content of the Curriculum
(Source: Prifti, Knigge, Löffler, and Banova (2017))

A curriculum overview as shown in Figure 21 is offered at the beginning of the application. This is helpful since it makes a connotation between the curriculum and the content. Each of the boxes represents the modules and can be clicked for accessing the content at a deeper level. An example of one of the modules is shown in Figure 22. By clicking on the first box “Strategy and Business Model Innovation”, the lecturers reach the content of the module. The content consists of two parts in the topics Business Models & Strategy and e3 Value. For each of this parts additional information is provided including the materials, a description of the learning outcomes, prerequisites and target group. By clicking on each box, the lecturers can access and download the materials.

Below the materials that were developed and delivered as part of this curriculum, additional online courses (MOOCs) are provided. This offers the possibility to go deeper into specific topics, or the lecturers can combine MOOCs with the other delivered content in form of blended learning. For each of the linked MOOCs also a course description, duration and the description of the target audience is provided. In this way the most important information is directly provided in the HTML application and this offers the lecturers the possibility to easily gain an overview on the MOOC and decide whether it is relevant for them or not.

The learning journeys are a further tool provided to help the lecturers if they want to give a deeper insight to a certain topic to their students. A learning journey is a combination of the developed content and existing MOOCs that gives a deep dive in a topic of interest. For different topics, different learning journeys are provided. The learning journey can also be target group or content specific, and serves as a tool of planning the learning process in the area of Industry 4.0.

In addition a course calculator is offered. The calculator helps the lecturers in better planning their courses based on the delivered curricula. As mentioned the curricula is not meant to be completely conducted in one class in one semester. It offers moreover content that can be mixed and applied depending on the area of interest or the target group. For helping the lecturers in better planning their courses the course calculator is provided. The lecturers can enter the number of weeks that they have for conducting the course and choose the content of interest. The tool calculates the time and suggests if additional learning units can be conducted if additional time is available.

As a last part of the HTML application a Glossary containing definitions for the main concepts of Industry 4.0 and the Digital Transformation is provided and an Abbreviation List containing the abbreviations used through the curriculum as well as common abbreviations in the handled topics.

4.4.6 Learning Units Content

The content of each learning unit includes different elements with theoretical and practical parts and by combining different learning methods. Each unit has a different structure that varies based on the topic. Some units have a more technical nature, while others focus on strategical and managerial topics. Below the content types that are delivered through the units are described:

Theory Slides: Theory slides are presented in every module and for every learning unit inside a module. The slides provide the basic theoretical concepts and an introduction to the topics at hand. The provided theory is provided from actual literature. After presenting the theoretical concept a connection to the Global Bike story and how the theoretical concept is presented with regards to the story is presented.

The slides can be used for self-study and fulfil the competency of life-long learning. However since the target of the curriculum includes universities and lecturers, the goal is mainly not self-study but a lecture that can be conducted in class. It means that the slides are delivered mainly for being used and applied in form of a lecture. Lectures are applied in universities worldwide and provide the basic method for transmitting knowledge. They offer the lecturer the possibility to present the content to a bigger auditorium (Tiberius, 2011; TUM Prolehre, 2016) and the students take a more passive role. There is normally no interaction in this learning process (TUM Prolehre, 2016) and therefore it is often called frontal teaching (Tiberius, 2011).

There is critique that this is not the most effective part of teaching, however it offers a good opportunity to give an overview on a broad subject or to provide an introduction to a specific topic (TUM Prolehre, 2016; Voss, 2006). Additionally some interactive elements were included in the slides in order to make the process more exiting and fulfil the constructivist approach as recommended by Biggs (2014).

Furthermore the suggestion of Voss (2006) were taken into consideration that a good designed lecture should provide:

- Clear and unambiguous goals of the lecture (by this is meant which central skills, phenomena, facts, concepts, models and methods should be learned) – therefore the provided content are competency-based and based on clearly defined learning outcomes.
- Professors should also consider content of other lectures in advanced semesters. This will help to gather information about the function of his own lecture – to fulfil this criteria discussions and focus groups were conducted and the design thinking approach was taken into consideration in order to take into consideration the needs of the lecturers and also gather the status quo of their teaching
- Selecting the content should take into consideration the knowledge that is required from the companies in the job market. This allows to renew old knowledge and practice. – to address this aspect, competencies based on requirements from research and practice were gathered and taken into consideration while developing the curriculum, furthermore the content was delivered based on research and practical literature. In this way it is guaranteed that relevant knowledge is taught.

However, for a better understanding and deepening of the presented content, the lecture need to be combined with other teaching forms (Schmidt & Tippelt, 2005), therefore additional methods were applied that will be described below.

Exercises: The curriculum includes also exercises as one of the offered practical elements. Exercises are often used in university teaching as an accompaniment of the lecture. By including them in the curriculum it offers a well-known teaching method that students and lecturers are familiar with. They serve in this way as an introduction to practice before going further to interactive teaching elements that are more complex, and also require a well prepared lecturer, capable of interacting and leading the interactive class.

Exercises represent an action-oriented approach of teaching (Tiberius, 2011). They use practical aspects and help in creating and transferring the knowledge. Nevertheless, the exercises should include, review and discuss material from the lecture. This interlinks both teaching formats (TUM Prolehre, 2016). Furthermore the exercises apply the theoretical knowledge presented in class on the practical example of Global Bike.

This teaching format deepens the theoretical knowledge and provides a better understanding of the presented concepts (Reumann, Mohr, Dössel, & Diez, 2007).

Case Study: Case studies are similar to exercises. By demonstrating solution strategies on case studies it supports students in transferring theoretical knowledge into practical actions (TUM Prolehre, 2016). However in the curriculum, case studies cover often more complex problems in comparison to exercises that should be solved in a team. While exercises serve as an introduction to the problematic and content, the case studies are more advanced and help in deepening the knowledge of the lecture.

Similar to the exercises, they build on the Global Bike story by developing it further. However differently to the exercises, they combine also elements of case based teaching and role play. In the case studies the students do not have to simply discuss or solve an issue about the company. More than that they are put in the role of company employees that need to solve a challenge and present it to the manager. This structure helps the students in being more motivated.

Discussions: One of the elements provided in the curriculum are the slide decks described above that can be used as the basis for the lecture. Schmidt and Tippelt (2005) suggest to combine this method with further ones in order to bring interactive elements. Therefore discussion slides are combined with the theory slides. After a new concept is presented, discussion slides are introduced. In the slides the theory concept that was presented is discussed in the context of Global Bike. In this way discussions offer an interactive element that breaks the monotony of the lecture and create room for idea building and concretizing the presented concepts in concrete examples.

As an additional tool for the discussions two modern interactive tools are provided. The first one is AnswerGarden[18]. It provides an online tool where the lecturers can ask a question and gather opinions in form of a brainstorming. The students should than recall the questions link through their laptops or mobile devices and enter their idea. The answers are provided in real time as a word cloud. In this way the lecturer can use this tool as a basis for brainstorming and discussions.

A further tools that is applied is onlineTED[19]. This is a tool provided by the Technical University of Munich. In this tool the lecturers can create a question and put different alternatives as answers. The lecturer can project a QR code with the beamer and the students reach the question by scanning the code with their smartphones. They can then choose one alternative and the tool

[18] https://answergarden.ch/
[19] https://www.onlineted.de/

evaluates in real time, how many students gave which response. This is a further possibility to be used for discussions.

Learning Assessment: Learning assessment is important in making sure that the learning units keep their relevance and vitality (Snoke & Underwood, 2002). It helps in keeping the students interested in a taught subject and in avoiding enrollment decrease (McCoy, Everard, & Jones, 2013). Addressing the audience is an appropriate way to maximize the educating value and to increase the students 'confidence with the presented skills (Kurnia, 2007). Therefore In each of the theoretical slides, assessment questions are provided. In this way, the students can test what they have learned. The lecturers can have a better overview of the class' progress and can check whether they could keep going or should repeat something.

MOOC: (Massive Open Online Courses) are courses, provided online via internet services to an unlimited numbers of students (Atiaja & Proenza, 2016). Atiaja and Proenza (2016), define MOOCs as *„[...] online courses that allow a massive and open participation on certain platforms, whose main components are as follows: a collection of videos of recorded classes by a renowned professor from a prestigious university (...), links to material support, automated assessments, discussion forums and peer reviews, providing greater accessibility to a flexible and ubiquitous education"*.

Friedman (2013) expresses the view that MOOCs should gain increasingly importance in the education of students: *„Institutions of higher learning must move, as the historian Walter Russel Mead puts it, from a model of "time served" to a model of "stuff learned." ". So he outlined, that nobody will care „ [...] how (students) acquired the competency [...]"* (Friedman, 2013), but be interested in the proof of their competency and skills.

There are no MOOCs directly provided in the curriculum, online available MOOCs are selected based on their content and linked in the curriculum, by describing them and its relevance. In this way the students and lecturers can use the offered MOOCs for going deeper in a presented subject or for focusing on a special aspect of it.

Hands-On: The curriculum covers strategical and technical aspects of Industry 4.0. With regards to the technical aspects and by taking into account the principles of constructivism and experiential learning hand-on exercises are included in the curricula. Hands-on exercises can be conducted in an SAP S/4 HANA and SAP HANA system. The both technologies were chosen as state of the art offerings that support some of the principles of Industry 4.0 and digitalization, as real time data processing, in-memory databases and so on. To cover the technical aspects from a technical perspective hands-on exercises on the systems mentioned above are provided. This gives a concrete example of the Industry 4.0 technologies and their usage.

The hands-on tend in addressing basic competencies by using the mentioned systems. The gathered knowledge is than transferable to other scenarios and can be applied for other products.

Lecturer Notes: Apart from the mentioned content described above in some cases as in some case studies or hands-on exercises lecturer notes are provided. The notes provide a help for the lecture organizing the learning unit. It helps them in better preparing and underlines the critical points and most important aspects to be taken into considerations. The lecturer notes are not available for every case study or exercise but only in cases where it is important in clarifying some aspects and where the presented case may be difficult and an additional clarification for the lecturer is required.

4.5 Modules Content

The curriculum includes 19 modules, six of each were developed in the context of this thesis. Some of the modules have a cross-cutting character, meaning that they can be applied in connection with many other topics provided in the curriculum. Other modules are focused on specific topics and aspects. These ladder modules can be categorized in two bigger categories: The technical focused and the ones that have a more strategical and organizational focus. The nature of the two kind of content creates also space for two kind of different structures and learning methods.

It is not possible to describe each single aspect of every content developed in the context of this curriculum. For this purpose the readers can access the curriculum themselves[20]. Therefore in this paragraph an example of each kind of module will be described and also the cross cutting content will be presented, which can be applied in each module for different purposes and in different creative ways that can be defined by the lecturer. These serve as an example, in order to understand the structure of the curriculum from the pedagogical and didactical perspective.

4.5.1 Cross Cutting Content

Some of the modules and content provided in the curriculum have a cross cutting character, meaning that they are interconnected with all the other provided topics. This includes content as: Digital Security, Social Media, Smart Data Analytics and SMAC. This topics are relevant for every other aspect of the digital economy. Additionally the whole curriculum is built on a teaching case, which provides a ground story for the learning content. A design thinking module, that can be applied in each other module for developing creative solutions is also provided as cross cutting content. In this paragraph a description of the teaching case and the design thinking module are provided, as these two cross-cutting contents were developed from the author of this thesis.

4.5.1.1 Teaching Case

The provided teaching case sets the grounds for the whole curriculum. It tells the story of the Global Bike Company and the challenge that the company is undergoing as they introduce the IoT bikes. Due to lacked success of the bikes the company decides to offer the developed IoT bikes as city rental bikes by transforming the business model to a PSS provider (Prifti, Knigge, et al., 2018).

[20] The curriculum can be accessed under: http://dt.sapucc.in.tum.de/

The case follows the principles as recommended by Farhoomand (2014), Cappel and Schwager (2002) and Hackney et al. (2003). The case is written in a way that it has two possibilities of how it can be applied in teaching:

- As a classical teaching case: it provides a story, a challenge and possible assignments at the end. The case can be used and applied as a single teaching case and the story itself provides enough information and material to be applied directly in class without any connection to the curriculum.
- As an umbrella teaching case for the curriculum: in this case it provides the story where the whole curriculum is based. It serves as a foundation for the different challenges that are set at every learning unit or case study in the curriculum itself.

In this way the teaching case provides an interactive and creative tool that the lecturers can apply in class while teaching concepts of the digital transformation.

As it is required in most teaching cases teaching notes with relevant information about the challenges and tips how the case can be applied are provided.

4.5.1.2 Design Thinking

The design thinking content provides a slide deck with the necessary information as well as design thinking tools for the lecturers to be able to apply the method in class. The method is provided in a way that offers the lecturers the possibility to freely apply it to any question or challenge they want.

The slide deck provides two challenges at the beginning. However this challenges are examples that could be used. The lecturers themselves can use the method and go step by step through the five phases for different challenges. The method can be combined e.g. with the teaching case, in order to solve some of the challenges of the digital transformation provided in it. But it can also be combined with other learning units. E.g. the business model canvas in order to deliver creative ideas how the business model of the company could look like. Furthermore it can also be combined with more technical questions and be used in defining what kind of sensors are necessary for the bike and how they could be applied.

The provided design thinking content is in this way a tool that can be used from the lecturers in different ways and offers a possibility to offer a creative and out of the box learning unit for motivating the students and teach them behavioral competencies in relation with the discussed content.

For students and lecturers that wish to go deeper into the topic and its possible applications a list of available MOOCs is provided for the design thinking topic.

Developing Software Using Design Thinking[21]: The course offered by openSAP[22] lasts 6 weeks and includes 3-5 hours of work a week or a total of 18-30 hours. This openSAP course introduces Design Thinking. “To start down the path toward innovative solutions, we focus on the problem first: We develop empathy for our users by “putting [ourselves] in their shoes”, and further understand their perspectives by defining a point-of-view statement. From there, we will start generating ideas and then move on to building low-resolution prototypes, which we can take back to our users for feedback. This will prepare us for the deliver phase, where we will learn how Design Thinking is connected to lean principles and single-piece processing. The target audience is anyone interested in Design Thinking, software professionals, and university students.”

Design Thinking for Innovation[23]: The course offered by Coursera[24] lasts 5 weeks of 1-2 hours of work a week and 5-10 hours in total. In this Coursera course, “an overview of design thinking and work with a model containing four key questions and several tools is provided. Participants learn to understand Design Thinking as a problem solving approach. We also look at several stories from different organizations that used design thinking to uncover compelling solutions. The target audience are economics and information system students and lecturers interested in topics of design thinking and its application.”

SAP's UX Strategy in a Nutshell by Sam Yen[25]: The openSAP course includes 6 videos and 2-3 hours in total. “In this openSAP course, the SAP User Experience (UX) strategy is introduced. Using the principles of design thinking, we maintain our core value of listening to our customers’ needs and quickly incorporating their feedback into SAP products. With the influence of consumer software making its way into the enterprise, SAP’s UX strategy aims to meet users’ expectations of easy-to-use software in the workplace. Join Sam Yen, SAP’s Chief Design Officer as he explains SAP’s UX strategy. He reviews the history of design thinking at SAP, the core elements and products we provide to meet the strategy, and the real business value it brings to our customers. The target audience is anyone interested in SAP’s UX strategy.”

4.5.2 Detailed Content

Above two cross cutting contents of the curriculum were presented. The rest of the provided modules has either a strategical/conceptual character by including topics of a strategical nature

[21] https://open.sap.com/courses/dt1-1

[22] **openSAP (open.sap.com)** is an online platform offering Massive Open Online Courses (MOOC) for free after registration with a valid email address. The offering comprises courses closely related to SAP products as well as upcoming topics. The courses are targeted at different audiences including professionals, students, and other people interested in the IT topics. Courses run for 2 - 6 weeks with weekly and final assignments and a certification in the end. After that, course materials are freely available and can be accessed by everyone.

[23] https://www.coursera.org/learn/uva-darden-design-thinking-innovation

[24] **Coursera (www.coursera.org)** is an online platform offering MOOCs. Coursera works with universities and other organizations to offer online courses, specializations, and degrees in a variety of subjects, such as engineering, humanities, medicine, biology, social sciences, mathematics, business, computer science, digital marketing, data science, and others. Is one of the biggest MOOCs provider worldwide and is based in US.

[25] https://open.sap.com/courses/uxn1?locale=de

as e. g. Strategy and Business Model Innovation, Business Change Management, Digital Innovation Management, or topics of a technical nature, e.g. Technology Introduction, IoT. Integrating Sensors. Due to the different character of the two areas also the structure of the provided content as well as interactive elements and teaching methods vary. Therefore in this chapter an example of each of these modules is provided, in order to help the readers to gain an overview of their structure.

4.5.2.1 Strategical Module: Strategy and Business Model Innovation

In this chapter, an overview of a module with a strategical/organizational character as: Strategy and Business Model Innovation is provided.

4.5.2.1.1 Overview

The module covers the topic Strategy and Business Model Innovation. This topic is of interest for the digital transformation towards Industry 4.0, since due to new technologies new business models and strategies arise (Kagermann et al., 2013). Business models, innovation as well as strategy are also relevant competencies for Industry 4.0 (Prifti, Knigge, Kienegger, et al., 2017). Therefore a module is dedicated to this topic in the curriculum. While planning the module, the intended learning outcomes were defined according to the revised Bloom's Taxonomy (Anderson & Krathwohl, 2001). An overview of the main aspects describing the module as target audience, prerequisites, content description, teaching methods and applied media and tools are also provided in order for the lecturer to be able to plan the class upfront. Furthermore a list of the promoted competencies is provided. In this way the lecturers and students are able to better plan their learning path in order to learn the competencies they think that are relevant for them (Table 11).

Table 11: Module "Strategy and Business Model Innovation" - Details and Content (Source: Own Representation)

Prerequisites (recommended)	No prerequisites required. General understanding and basic knowledge on the main business concepts are of advantage.
Intended Learning Outcomes	At the end of the module, students learn to: • understand fundamentals of business strategy and business model
Audience	Students of Information Systems (Bachelor/Master) Students of Economics (Bachelor/Master) Students of Computer Science (Bachelor/Master) Students of Mechanical Engineering (Bachelor/Master)
Content Description	This module covers: • Business model significance and transformation • Strategy significance and transformation • Importance of services in modern business models • Business model canvas development and refinement

Promoted Competencies	This module aims in promoting following competencies: • Presentation and Communication • Teamwork Competency • Creativity • Critical Thinking • Decision Making • Business Strategy
Teaching Methods	The module will mix and match: lectures with debates, discussions, teamwork, creativity methods and presentations
Media/Tools	Slides Porter Strategy Framework SWOT Business Model Canvas E3 value

4.5.2.1.2 Structure and Content

The structure of the module is presented in Figure 23. The module consists of two learning units where each unit has a different content and contains theory and practical aspects as well as a list of recommended MOOCs for a deep dive into the topic. In the following sections the content of each learning unit is described.

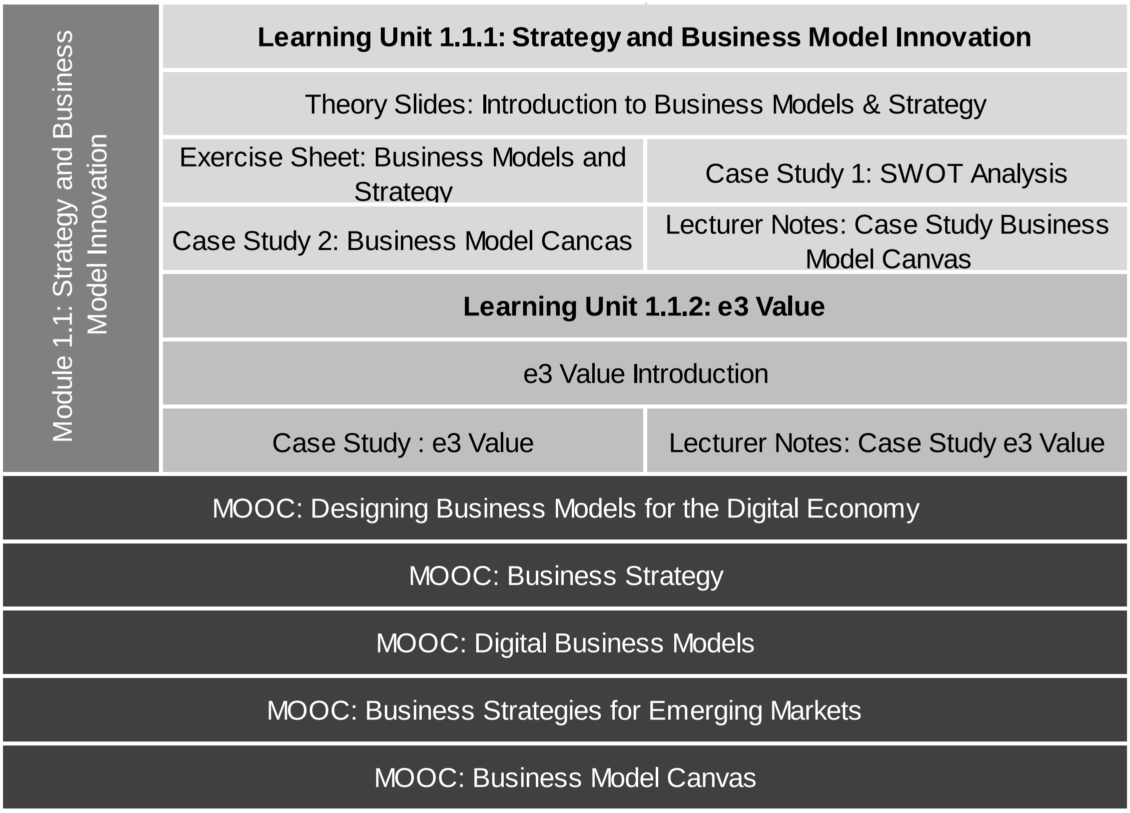

Figure 23: Module "Strategy and Business Model Innovation" - Structure (Source: Own Representation)

Learning Unit 1.1.1:"Business Model and Strategy":

Learning Outcomes:

At the end of this learning unit the students are able to:

- understand the fundamentals of business strategies and business models
- understand the innovation process
- understand the importance of business models and business strategies in the digital transformation
- understand the impact of digitalization on business models and business strategies
- understand the role of services in the business development
- use known frameworks for business modelling and strategy description
- evaluate existing business models and create new business models.

Learning Content:

Slide Deck: The slide deck starts with a description of the learning objectives. This helps the lecturers in having concrete expectations and better understand the presented content. This learning unit gives an introduction in the main aspects of the topic. The theory slides start with an introduction to the concept of strategy and go deeper in the connection between strategy and the digital transformation, by underlining the importance of strategy in the digital era. Afterwards the strategy types according to Porter (1980) are presented and it is explained how they play a role in the digital transformation. At this point a discussion slide regarding the strategy type of Global Bike is presented. It offers the lecturer an interactive element to activate the class and make them an active part of the discussion. The Global Bike story helps also in better understanding the explained concept, since it is based on a known example which is exploited and analyzed with connection to the topic at hand. The strategy introduction is rounded up with an introduction in different strategy frameworks that are usually used in research and practice including Porter 5'Forces (Porter, 1980), SWOT Analysis, BCG Matrix (Henderson, 1970) as well as Porter Value Chain (Porter & Millar, 1985).

The slides continue with an introduction in the concept of business model by discussing different definitions of the concept from different points of view. This gives the students the possibility to better understand the topic from different dimensions. Afterwards the elements of business models are presented followed by a discussion in which the business model elements of Global Bike should be analyzed. The next part introduces the Business Model Canvas as presented by Osterwalder, Pigneur, and Smith (2010) and presents the single elements of the canvas by explaining each of them. To give a better understanding on the topic of the Business Model Canvas examples of modern companies that are well known and successful in the digital transformation as Apple, Facebook and Google are presented. By taking such well known examples it offers the advantage that everyone knows the companies as well as their products or services, so that it is a modern and practical related content that gives the students the possibility to easily understand it and have the feeling that they are learning something that is relevant and actual.

At the end the business model innovation and innovation archetypes are introduced based also on some examples from practice. The theory part at the point ends with the business model patterns as recommended from Gasmann, Frankenberger, and Csik (2014). Some key and well known patterns that are widely applied are introduced by also mentioning some examples of well-known companies for each of them. After the presentation of the patterns the chapter closes with a discussion of the business model patterns of Global Bike that gives the students and lecturers once more the possibility to reflect over the theory that they learned as well as the ability to better consolidate the knowledge by using practical example.

At the end of the slide deck an assessment follows. This includes several questions regarding the content. It includes open as well as multiple choice questions. The questions are used as a control mechanism at the end of the unit for lecturers and students. The solutions to the questions are also provided.

Exercise Sheet: The exercise sheet provides three exercises by going deeper in the discussion topics presented in the slide deck. This can be used in class to discuss the topic or if desired as a homework exercise sheet. The exercise sheet presents three exercises:

- Exercise 1: Strategy Types according to Porter: In this exercise the three strategy types according to Porter (1980) are presented and also a theoretical explanation for each of them with examples is provided. This part is for self-study so that the students can get deeper into the topic and recall once more what they learned in the lecture. The task that follows consists on a discussion of the strategy type of Global Bike.
- Exercise 2: Business Model GBS: The exercise sheet starts with a presentation of the magic triangle from Gasmann et al. (2014) and an explication of each of the elements of the magic triangle as the Who, What, How and Why. The task that follows consist in discussing the business model of GBS based on the four aspects.
- Exercise 3: Business Model Patterns according to Gassmann: In this exercise an introduction to the 55 business model patterns according to Gasmann et al. (2014) is presented. Afterwards 11 patterns are described in detail by mentioning companies who apply this pattern as an example as well as which Business Model component (Who, What, How, Why) is affected by each pattern. This helps the students in better understanding the patterns and create an overview of them. In the task they need to discuss the pattern that GBS follows and describe it in detail.

Case Study 1 – SWOT Analysis: The case study starts with a detailed description of the framework by creating the theoretical basis for the case study. It helps the students in refreshing their knowledge from the lecture as well as get introduced to the topic for the case study. Afterwards a scenario with regards to the GBS company follows, and the students are put in the role of a company employee and are given the task of conducting a SWOT analysis for a certain investment. This gives the students the possibility to position themselves as part of the company and gives a better connection to the topic and the challenge. The task instructions state that the students should work in teams and present the results of their work in presentation form. In this way behavioral competencies as teamwork, presentation, technical writing etc. are promoted. Furthermore the case study in the form of teamwork gives the possibility of interactive elements where the students can learn through their own experience and it is also fun for the students. A blank framework is provided to be used as a discussion basis for the students.

Case Study 2 – Business Model Canvas: The second case study starts with a video explaining the Business Model Canvas. In this way the theoretical introduction is interactive and fun. Videos are always welcome by the students and give a fast and easy overview of the topic. Afterwards the students are presented with a scenario in the company similar as in Case Study 1. They are put in the position as an employee of the company that have got a task from their manager. The task consists in analyzing a new business model opportunity for the company and use the Business Model Canvas for that. The students are requested to work in teams of 3-4 people and prepare a presentation as they would do for presenting the results to their manager. The case study combines again different competencies as teamwork, presentation, technical writing etc. and offers the possibility to work and discuss in an interactive environment. A blank framework of the Business Model Canvas is provided to serve as a discussion basis for the students and help them in the creativity process.

Lecturer Notes: The lecturer notes serve as an accompanying tool for the lecturers and are provided in cases where they are helpful for supporting the teamwork of the students and the discussions. In this case it delivers a value to have lecturer notes and describe how the Business Model Canvas can be used as well as a proposition for a possible solution. However the provided solution is not the single possible one, as in the case studies there is no right or wrong solution. Moreover it serves as an orientation for the lecturers to help them organize the teamwork and better assist their students so that they are able to make the most of the case studies.

Learning Unit 1.1.2:"e3-Value":

Learning Outcomes:

At the end of this learning unit the students are able to:

- understand the fundamentals of e³-Value method
- apply e³-Value method on a concrete use case.

Learning Content:

Slide Deck: The slide deck starts with an overview of the prerequisites, target audience as well as the intended learning outcomes in order to give the lecturers an overview and give them the possibility to better plan the learning unit.

After giving an introduction in the e3 value methodology and its meaning, the single elements of the methodology are presented and described in detail. This is followed by the description of the approach. At the end a concrete example of an e3 value model application is provided. Similar to the previous slide deck, the slide deck is closed by a collection of assessment questions consisting of opened as well as multiple choice questions to give the possibility to students and lecturers to recapitulate the content. The solutions for the single questions are provided at the end.

Case Study – e3 value methodology: The case study starts with a short description of the theoretical background regarding the e3 value methodology. The students are presented then with a scenario with regards to the GBS company, where they are put in the position of a company employee and are given the task to model the e3 value with regards to GBS. The task is given as teamwork and the students are required to provide an e3 value model for the new GBS company as a PSS provider. This task gives the students the possibility to work in teams and develop a wide range of behavioral competencies as teamwork, presentation, technical writing etc. Additionally it is an interactive learning part that gives the possibility for discussion and interaction.

Lecturer Notes: In this case lecturer notes are provided as a guidance for the lecturers in order to help them arrange the learning unit as well as be able to better lead and organize the teamwork of the students. The lecturer notes also provide an example model of the GBS e3 value that could serve as an orientation for the lecturer in supporting their students. This is however not the only possible solution, since there are many possibilities in modeling the e3 value of the presented company

MOOCs for the Module

To give the lecturers and students the possibility of self-study, or to go further into a certain topic, a list of free available MOOCs is provided. This gives the possibility to get deeper into the topic. The provided MOOCs are listed below:

- Designing Business Models for the Digital Economy[26]: The course is offered from openSAP. It consist of 6 weeks of ca 3-5 hours a week and comprehends 21 videos by achieving a total of 24 hours. "In the course, participants use the Business Model Innovation (BMI) approach for designing business models and improving them iteratively towards the most appropriate business model. They learn about the motivation behind and relevance of BMI. They experience a full iteration cycle, starting with the design of an initial business model baseline. The participants learn how to analyze specific elements of their business models, challenge their entire business models, test the key assumptions underlying their business models with customers, and finally pick the most appropriate business model from a number of alternatives." The target audience includes everyone interested in business models and business model innovations, lecturers, and students.
- Business Strategy[27]: The course offered by Coursera consists of 4 weeks of 3-6 hours per week and a total of 20 hours for the whole course. "In this course it is explained how organizations create, capture, and maintain value, and how it is fundamental for sustainable competitive advantage. Participants will be able to better understand value creation and capture, and learn the tools to analyze both competition and cooperation from a

[26] https://open.sap.com/courses/bmi1
[27] https://www.coursera.org/learn/strategy-business

variety of perspectives, including the industry level (e.g., five forces analysis), and the firm level (e.g., business models and strategic positioning)." The target audience are economics and IS students interested in topics of business strategy and innovation

- Digital Business Models[28]: The course is 4 weeks long, where each week lasts 2 to 3 hours and a total of 10 hours for the complete course. "This Coursera course will explore the business models of software disruptors of the west such as Apple, Google, Facebook and Amazon, and the east such as Xiaomi and weChat. The class uses a structured framework for analyzing business models with numerous examples so that students can apply it to their own business or case study. The target audience are economics students, business strategists or senior executives wishing to understand the nature of disruption that is happening to industry after industry – and to better understand how to apply these same techniques to extend their own business or case study."
- Business Strategies for Emerging Markets[29]: The course is 8 weeks long and needs 4-6 hours per week and a total of 40 hours. "This Cousera course aims to transfer the fundamental knowledge and to form the basic competencies necessary for the development and the implementation of a business strategy in an emerging market." The target audience are master students, MBA students and entrepreneurs.
- Business Model Canvas[30]: A Tool for Entrepreneurs and Innovators (project-centered course): The course offered by Coursera is a project centered course covering a total of 4 hours of study and ca 10 hours of active project work. "In this project-centered Coursera course, participants use the Business Model Canvas innovation tool to approach either a personal or corporate challenge or opportunity. They learn to identify and communicate the nine key elements of a business model: Customer Segments, Value Proposition, Channels, Customer Relationships, Key Resources, Key Activities, Key Partners, Revenue Streams, and Cost Structure. The target audience: This is an introductory course on the Business Model Canvas. Learners do not need to have any previous experience using the Business Model Canvas, as each of the nine-segments will be defined."

4.5.2.1.3 Learning Journey

With regards to the topic and as an extension of the module, a learning journey is provided with focus on business model and strategy. The journey is depicted in Figure 24 and provides a closer look into the topic. The target audience are students of Information Systems and Economics (Bachelor/Master).

The learning journey starts with an introduction in the topics of Business Model and Strategy that should be conducted by using the introduction slides as well as the exercises and case studies. After this the students have gathered the right prerequisites to go deeper into the topic. Therefore the module Business Change Management is suggested afterwards for a deep dive. The module includes theory slides as well as exercises and case studies. Further on students can follow the online MOOCs "Business Strategy" and "Digital Business Models" as part of self-

[28] https://www.coursera.org/learn/digital-business-models
[29] https://www.coursera.org/learn/business-strategies
[30] https://www.coursera.org/learn/business-model-canvas

study. As a special topic the MOOC “Business Strategies for Emerging Markets” is suggested. At the end, after completing the learning journey, the students have good knowledge about the topic and have developed adequate competencies in the dimension of communication but also in the dimension of self-development, since they apply MOOCs and self-learning. The lecturers can use a learning journey as a whole learning experience in a course and combine class learning and MOOCs in form of blended learning.

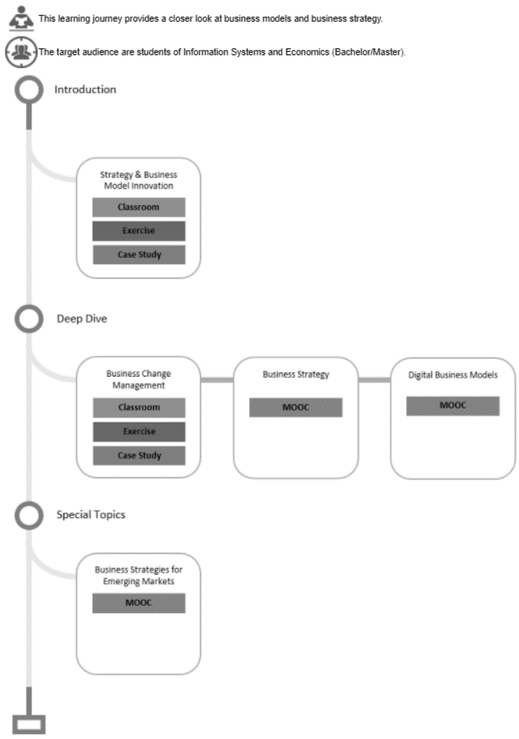

Figure 24: Learning Journey: Business Model and Strategy (Source: Prifti, Knigge, Löffler, and Banova (2017))

4.5.2.2 Technical Module: IoT: Integrating Sensors

4.5.2.2.1 Overview

Sensors are one of the basic developments that will emerge in Industry 4.0. The machines, tools, data and people will be interconnected with sensors and will generate data that should be processed. While planning the module the intended learning outcomes were defined according to the Revised Bloom’s Taxonomy. An overview of the main aspects describing the module as target audience, prerequisites, content description, teaching methods and applied media and tools are also provided in order for the lecturer to be able to plan the class upfront. Furthermore a list of the promoted competencies is presented. In this way the lecturers and students are able to better plan their learning process (Table 12).

Table 12: Module "IoT – Integrating Sensors" - Details and Content (Source: Own Representation)

Prerequisites (recommended)	No prerequisites required. General understanding and basic knowledge of main IT concepts are of advantage.
Intended Learning Outcomes	At the end of the module, students learn to: • understand the main concepts of IoT • analyze and apply sensor data for generating value
Audience	Students of Information Systems (Bachelor/Master) Students of Computer Science (Bachelor/Master)
Content Description	This module covers: • Fundaments of IoT and sensor data • Fundaments of sensor data collection • Fundaments of data analysis and reporting • Fundaments of predictive maintenance and machine learning
Promoted Competencies	This module aims in promoting following competencies: • Machine Learning • Predictive Maintenance • Big Data/Data Analysis and Interpretation • In-Memory DBs
Teaching Methods	The module will mix and match: lectures with debates, discussions, hands-on exercises, case studies
Media/Tools	SAP HANA Rasperry Pi HANA Studio

4.5.2.2.2 Used Technology

Since the module has a technical focus, various technologies are applied in order to make the learning process more practical and interactive. The technology used in this module is presented below.

Raspberry Pi[31]: The Raspberry Pi is a single board computer produced by the Raspberry Foundation. It is used for teaching purposes in order to learn programming and technology. There are many sensors available that can be connected to the Raspberry. In this way it can be used for many different purposes. In this module the Raspberry Pi is connected to various sensors and used as a tool to simulate the bike sensors. It offers the students the possibility to conduct some hands-on exercises with hardware. In case that a Raspberry is not available, a ready to go

[31] https://www.raspberrypi.org/

data set generated beforehand is provided, so that lecturers and students do not need to skip this unit. However it is recommended to use a Raspberry for a better learning experience.

SAP HANA: SAP HANA is an in-memory database of the software company SAP SE[32]. It serves as a database and makes it possible to save and recall data faster through the application of in-memory technology. Through the software HANA Studio, available in SAP HANA it offers advanced reporting and analytics, as well as real time analysis and predictive calculations. By applying this technology in the module the students get to know a state of the art tool and can conduct real hands-on analysis as they would do in a company.

SAP Lumira: SAP Lumira is a business intelligence software offered by SAP SE. It is used to visualize data. E.g. after analyzing the data in SAP HANA Studio, they should be visualized in order to be able to understand the content and have a better overview of the data. By using this software the students get the chance to visualize the conducted analysis and discuss the results. Additionally it offers the possibility of gaining hands-on experience with a state of the art software that is used in companies.

SAP HANA Predictive: This functionality is included in SAP HANA Studio through the PAL library. It provides a collection of algorithms that are typically used for predictions. By including them in the case studies the students get an overview of the most used algorithms in the companies and learn hands-on experience on the SAP HANA Predictive tool.

4.5.2.2.3 Structure and Content

The structure of the module is presented in **Fehler! Verweisquelle konnte nicht gefunden werden.**. The module consists of four learning units. Each learning unit is focused on one aspect of the topic. A list of recommended MOOCs for a deep dive into the topic is also provided.

Learning Unit 2.4.1: IoT: Integrating Sensors - Introduction

Learning Outcomes:

At the end of this learning unit students are able to:

- understand fundamentals of sensor technology
- understand the relevance of sensors for IoT
- understand the challenges of sensor usage
- understand main applications of sensor technology
- Understand business scenarios and IoT products enabled by sensor technology.

[32] https://www.sap.com

Learning Content:

Slide Deck: The slide deck starts with a description of the learning objectives and the target audience. In this way it gives the students and lecturers the opportunity to understand what to expect from the unit. This unit gives the theoretical basics of the topic. It starts with an introduction in the IoT topic and description of the importance of sensors in IoT scenarios by listing and describing different kind of sensors used in IoT products.

Module 2.4: IoT - Integrating Sensors	**Learning Unit 2.4.1: IoT Introduction**	
	Theory Slides: IoT Integrating Sensors - Introduction	
	Learning Unit 2.4.2: IoT Data Collection	
	Theory Slides: Data Collection with Sensors	Lecturer Notes: Data Collection with Sensors
	Case Study: Data Collection with Sensors	Sample Solution: Data Collection with Sensors
	Learning Unit 2.4.3: IoT Data Analytics & Reporting	
	Theory Slides: Data Analytics & Reporting	Lecturer Notes: Data Analytics & Reporting
	Case Study: Data Analytics & Reporting	Sample Solution: Data Analytics & Reporting
	Learning Unit 2.4.4: IoT Maschine Learning	
	Theory Slides: Maschine Learning with Sensors	Lecturer Notes: Maschine Learning with Sensors
	Case Study: Maschine Learning with Sensors	Sample Solution: Maschine Learning with Sensors
MOOC: How the Internet of Things and Smart Services Will Change Society		
MOOC: Imagine IoT		
MOOC: Cybersecurity - The Essential Challenge for Digital Transformation		
MOOC: Cybersecurity and the Internet of Things		

Figure 25: Module "IoT - Integrating Sensors" – Structure (Source: Own Representation)

In the next section it goes deeper into the description of the sensors technology, by describing how it works, the structure of a sensor node and so on. The following section focuses on the challenges that arise from the usage of sensors in IoT and how they could be addressed. This is followed by the next section that describes main application scenarios and modern products in the area of IoT.

Further, the deeper connection between sensors and IoT scenarios is described by focusing on the business view, functional view, usage view, implementation view and specifications view of these applications. At the end the IoT bike of GBS is presented by listing its sensors and describing their functionality in detail. In this way the theoretical aspects that were explained are connected with the concrete case of GBS. The slide deck ends with an assessment part, where control questions and answers are provided for lecturers and students to test their understanding about the topic.

LU 2.4.2: IoT Data Collection with Sensors

Learning Outcomes:

At the end of this learning unit students are able to:

- understand how a Raspberry Pi works and how to set it up initially
- distinguish the technical features and characteristics of different sensors and analyze their differences
- establish a connection to a sensor from a Raspberry Pi
- implement a Python script for automated sensor data collection from IT architecture and software perspective
- import data to a SAP S/4 HANA in-memory database and visualize it in SAP HANA Studio from IT architecture and software perspective
- integrate heterogeneous and interdisciplinary technologies into a holistic solution
- evaluate concepts and the purpose of IoT devices in innovative business models
- evaluate solutions for common challenges of Bike Sharing Service Providers
- apply knowledge, solve problems and develop solutions in a team.

Learning Content:

Slide Deck: IoT is about sensors and while dealing these sensors the first step is collecting the sensor data. Therefore after the introduction in the previous learning unit, this slide deck starts with the data collection of sensor data. At the beginning of the slide deck general information regarding the target group, needed software as well as the learning objectives is described. In this way the lecturers and students can plan their unit from the beginning and know what to expect. To collect data a Raspberry Pi is involved to generate the data which is imported afterwards in the SAP HANA in-memory database.

In the first part the introduction in the bike scenario as well as the Raspberry Pi technology is provided. Since the Raspberry Pi is a hardware piece, an introduction to the electricity basics follows where the foundations of the electric circuit, electric breadboard, wires and jumper wires as well as resistors is presented. These are all necessary aspects in order to understand the basic functionality of the Raspberry Pi.

The next section introduces the Raspberry Pi and its functionality, starting with the foundations of Raspberry Pi 3, the actual version of Raspberry Pi that is used in this learning unit. This is followed by an introduction in the operating system used by the Raspberry, Raspbian as well as an introduction in the GPIO interface that is the interface for connecting and programming sensors with the Raspberry. Afterwards two sensor types and their circuit diagrams are introduced and explained, a temperature sensor and a humidity sensor. In this way a complete introduction to the used hardware is provided.

The following part introduces the SAP HANA database. At first the concepts and functionalities of the in-memory databases are explained. Afterwards an introduction in the SAP HANA Studio as a central development and administration platform for SAP HANA is conducted. The main aspects and functionalities are explained by using screenshots.

The last part provides a crash course in the programming language Python. Python is commonly used for programming the Raspberry Pi and makes a connection of the Raspberry Pi with the SAP HANA possible. In this way all the necessary foundations for working with the sensors and the Raspberry as a data generator, and connecting them to SAP HANA are delivered. The slide deck is closed with assessment questions to check the gathered knowledge.

Case Study: After delivering an introduction to the main concepts, a case study is provided that delivers a practical view on the content. The case study applies in practice all the concepts that were explained in theory. It provides a step by step tutorial of how sensor data can be retrieved by using a Raspberry Pi computer. This includes the Raspberry Pi setup as well as the implementation of an electronic circuit diagram with electrical components to connect the sensor to the Raspberry Pi. The final part of this case study also deals with the structured data import into a SAP HANA main memory database.

To make the story more attractive the case study is accompanied with a teaching case approach based on the story of GBS company. The problem setup is provided as a story by including story telling elements in order to make it more appealing to the students.

The case study is divided in five parts, in the first part it is introduced how to collect data with the Raspberry Pi. This starts with setting up the Raspberry, connecting the sensor to the Raspberry, activate the protocol and receive the first data. Each step is described in detail and illustrated with pictures and screenshots.

In the second part the sensor data is collected automatically with the help of Python code. This step starts with an adjustment of the Python code. So the Python code necessary for the automation is already provided in case that the students do not know how to program or do not have the necessary time. Some questions with regards to the code are provided in order to assure that the students still understand what they are doing. Of course some students or lecturers can decide not to use the delivered code and write it themselves. After setting up the code the students have to run it.

In the third part the generated sensor data is imported in the SAP HANA. At the beginning it is explained with screenshots how the login in HANA works with the help of SAP HANA Studio.

In the first step then the students have to import a provided csv file and use some easy functionalities of SAP HANA studio to conduct some basic visualizations.

In the fourth part a second sensor is introduced. By introducing a second sensor it offers the possibility to try the whole process once again from a different perspective. The students gather this way the necessary know how and can afterwards add other sensors if they want. In the fifth part it is also explained how the sensor data can be collected automatically using a Python script.

Sample Solution: The sample solution provides detailed solutions for each part and each step of the case study above. It is described thoroughly and accompanied with screen shots at every step. The sample solution is available for the lecturers who can decide to use it as they wish. On the one way they can look up the solutions for themselves and try to help the students. A further possibility is to give it directly to the students and then discuss the solutions. This could be the case if the students are not advanced in technology e.g. if they do not study a technology oriented course but still want to learn the basics of sensors.

Lecturer Notes: The lecturer notes provide a detailed description for the lecturer. They describe the goal of the presented theory and case study and how they should be used. It also describes how to set up the technical environment and how the delivered content can be applied in class.

LU 2.4.3: IoT Data Analytics and Reporting with Sensor Data

Learning Outcomes:

At the end of this learning unit students are able to:

- understand a complex data model and a big data set (mostly) retrieved by sensors implementing it
- apply technical and conceptual knowledge in order to model a big data set to increase the information value using an example data set
- prepare big data in order to be suitable for decision making
- work with SAP HANA Studio and SAP Lumira
- model a big data set in a SAP S/4 HANA environment
- put statistics into a business context
- interpret big data and analysis results in a business context
- visualize big data and analysis results for business reports
- present data and analysis results in a business context
- critically analyze arising trends in a business and appropriately adjust business strategy
- integrate heterogeneous and interdisciplinary expertise into a holistic solution
- apply knowledge, solve problems and develop solutions in a team.

Learning Content:

Slide Deck: This learning unit focuses on data analytics and reporting. Also in company scenarios, where sensor data is used, this would be the next step to be applied after collecting the data as conducted in the previous learning unit. After collecting the data, it should be analyzed in order to make sense of it, and reports should be created so that it is possible to use them for decision making purposes. For an easier overview the reports can be visualized.

The slide deck starts similar to the others with the learning objectives, target audience as well as a list of the needed prerequisites and used software.

In the beginning of the slides an introduction to the GBS bike and the problem setup of the slides with regards to the data analytics is conducted. This creates a foundation needed to understand the further content.

It is followed by a short introduction in SAP HANA and SAP HANA Studio. Afterwards the data modelling concepts are explained and it is also explained how they could be used in SAP HANA. The data modelling is an important step at the beginning of the data analysis. The main operators, the meaning of the columns as well as the data structure in HANA are also explained and illustrated with screenshots. In this way the basics for using analytics in SAP HANA are provided.

In the last part SAP Lumira is introduced. SAP Lumira is a visualization tool offered by SAP SE. It is used in combination with SAP HANA to visualize the reports and analysis of the data created in HANA. In this way it provides a better interface and a better overview of the data. An introduction to SAP Lumira is presented followed by an explanation of its architecture, and a visualization approach. All steps are illustrated with screenshots. At the end of the slides there is a list of assessment questions in order for lecturers and students to assess their knowledge and decide if they understood the subject matter.

Case Study: This Case Study provides a step by step tutorial of how collected (sensor) data can be used for generating a business reports by using data analysis and visualization tools. This includes the development of a suitable data model followed by the implementation of dynamical views in SAP HANA. In the final part of this case study the implemented dynamic view is used to analyze and visualize the data and thereby draw conclusions regarding business performance.

The case study starts with an introduction in the background of the Global Bike story as well as a presentation of the challenge in form of a problem connected to the Global Bike company. The challenge is described step by step and consists in analyzing data regarding to trips conducted from the rental bikes of GBS.

At the beginning it is explained how to log in to SAP HANA Studio and create an entry for the SAP HANA. This provides the foundation so that every student, with or without previous knowledge is able to use it.

The first part starts with the data model and modelling approach which is conducted step by step. The data source is already provided in the system. The student are requested to access three types of data the customer trip records, the rental station data as well as the weather data. Through easy SQL statements the students get to manipulate the data and change them for their needs. In the last step they create the data model and can also generate a dynamic view based on the model.

After modelling the data, the students generate a dynamic view in the second part of the case study. In the first step the students create a repository package where they can create the views. Afterwards they create views for the attributes and the calculation. The created views and existing tables are joined and aggregated on many levels in order to reach the desired outcome. Each required joint is presented and described as a single step as well as illustrated with a screenshot. The students have to aggregate the trips and create two calculated columns at the end.

After the data has been preprocessed, joined, analyzed, aggregated and calculated, the results of this actions can be visualized with the use of SAP Lumira in the third part of the case study. After importing the data in SAP Lumira a simple column chart is shown at first that shows how many trips for each month were conducted. After creating this simple visualization some questions are provided in order for the students to get to think about the content and discuss about it.

Sample Solution: The sample solution provides a detailed solution of the case study. It includes a solution and explanation for all steps by accompanying them with screenshots. Lecturers can use them to prepare for the lecture or they can give them to the students and discuss the solutions together.

Lecturer Notes: The lecturer notes provide information regarding the needed software, problem setup, requested preparation as well as the didactic concept of the case study and tips and tricks how to use it. The lecturers can use it to prepare for the case study. This is a document to be used from the lecturers and is not intended for the students.

LU 2.4.4: IoT Machine Learning with Sensor Data

Learning Outcomes:

At the end of this learning unit students are able to:

- understand a data model and a big data set (mostly) retrieved by sensors implementing it
- work with SAP Predictive Analytics and SAP Predictive Analytics Library algorithms
- apply technical and conceptual knowledge on an example data set in order to:
    - perform common preprocessing in a SAP S/4 HANA environment
    - train a machine learning model based on a big data set in a SAP S/4 HANA environment
- put statistics and complex statistical models into a business context
- interpret and visualize the outcome in a business context
- rate the value proposition of machine learning in business models
- identify and implement new revenue streams in innovative business models

- develop product customer oriented service offerings based on big data analytics and machine learning outcomes
- integrate heterogeneous and interdisciplinary expertise and technologies into a holistic solution
- apply knowledge, solve problems and develop solutions in a team.

Learning Content:

Slide Deck: Machine learning and predictive analytics play an important role in Industry 4.0. Therefore these topics are introduced in the slides for a holistic approach and understanding of the topic.

The slide desk starts with a presentation of the target audience as well as the learning objectives, followed by the needed software and prerequisites. To conduct this learning unit a general understanding and basic knowledge in data modelling is required as well as basic knowledge of SQL.

The slides start with an introduction in the GBS bike as well as a description of the problem step up. The introduction also discusses why it is important to conduct predictive analytics for GBS. Afterwards some foundations of knowledge discovery are introduced by describing and differentiating between the fields of statistics, data mining and machine learning. This is followed by introducing some basic algorithms used for knowledge discovery in the different steps of the process.

The next part introduces machine learning with SAP Predictive Analytics. It starts with an introduction in the SAP HANA Predictive Ecosystem as well as an overview of the architecture and installation options. This is followed by an introduction in the SAP Predictive Analytics Library (PAL) and its algorithms, which are listed and explained one by one for a better overview.

At the end the association analytics is presented as a simple and easy to understand analysis that is still broadly used and delivers reliable results. The association analytics is introduced and the main association rules are explained and accompanied with examples. This is followed by an example in order to better understand the algorithm. The slide deck ends with assessment questions that can be used for measuring the obtained knowledge.

Case Study: This case study provides a step by step tutorial of how collected (sensor) data can be used for generating new machine learning driven revenue streams. This includes preprocessing, model creation and execution based on data located in a SAP HANA system with SAP Predictive Analytics as well as understanding, visualizing and interpreting the results. Moreover, statistical ranking measures are introduced. In this way all the steps of data analytics and reporting that should be conducted after collecting the sensor data are presented and applied in hands-on exercises.

The case study starts with an introduction and description of the case by following the teaching case approach and connecting the concrete case study with the Global Bike story. In this way it is easier for the students to understand the whole background and content. Afterwards the problem setup is described by setting the challenge that should be solved in the case study. Two data sources are provided that are used for the analysis.

At the beginning an introduction to SAP HANA Studio and how to log in to HANA is presented. In this way even users that use the software for the first time are able to log in. In the first part the students have to create the data model. Therefore they need to access the data sources and can visualize the data as a table. They use then SQL statements to view the data model.

In the second part of the case study a dynamic view with SAP HANA Studio is generated. Therefore in the first step a repository package and the adequate attributes should be created. Some selections on the data are conducted by running simple SQL statements.

After conducting this preparation steps, the students start to use the SAP Predictive Analytics in the third part of the case study. For this the data should be imported in the SAP Predictive Analytics tool first. Afterwards some preprocessing as filtering or dealing with NULL values is conducted. This step is necessary in order to clean the data from unusable values that would lead to bad results. After the preprocessing the association analysis can be conducted by using the Apriori algorithm in SAP HANA. At the end the model can be executed and the results can be visualized by using the integrated HANA functionalities. Students can also use Lumira for the visualization, as it was presented in the case study before.

All the steps are provided with a detailed description and screenshots in order to better be able to conduct them.

Sample Solution: The sample solution provides detailed solutions to every part and step of the case study and is illustrated with screenshots. The lecturers can use it for preparation or can give it to students and discuss the solutions in class.

Lecturer Notes: The lecturer notes are provided for the lecturers only. They are not intended to be given to the students. They provide information about the software as well as requested preparation from lecturer part. Furthermore they provide information with regards to the teaching concept and tips and tricks on how to use the case study.

MOOCs for the Module

As in the previous module, also in this module a list of free available MOOCs is provided that can be used for self-study and gives the possibility to get deeper into the topic. The provided MOOCs are listed below:

How the Internet of Things and Smart Services Will Change Society[33]: The course is offered by openSAP and comprises a short overview of the topic. It includes 8 videos of 2-3 hours in total. "This openSAP course explains key terms and trends around the Internet of Things. Participants gain an understanding of the potential and value of the Internet of Things and Smart Services, and understand the opportunities and benefits for society, companies, and consumers". The target audience is anyone interested in learning about the Internet of Things.

Imagine IoT[34]: The openSAP course includes 17 videos for 12-16 hours in total. "This openSAP course shows how to use IoT to make life better. Participants learn the fundamentals of the Internet of Things (e.g., sensors, the cloud, and more) and are introduced to new interaction paradigms (augmented reality, wearables, and more) that are changing how we interact with the world around us. They will also learn how to design and create their own IoT prototype. The target audience are IT professionals, solution consultants, (mobile) application developers, user interface designers, and anyone interested in Internet of Things, Design Thinking, and prototyping."

Cybersecurity - The Essential Challenge for Digital Transformation[35]: The openSAP course has 8 video and 8-12 hours of learning in total. "This openSAP course deals with the challenges of cybersecurity that emerge from the use of the internet and connected devices everywhere in private and professional live." The target audience are students and business professionals.

Cybersecurity and the Internet of Things[36]: The Coursera course lasts 4 weeks of 2-3 hours per week and a total of 8-12 learning hours in total. In this course, "participants explore current security and privacy related concerns in each of these areas." The target audience are students and business professionals.

33 https://open.sap.com/courses/iot1
34 https://open.sap.com/courses/iot2
35 https://open.sap.com/courses/cs1-tl
36 https://www.coursera.org/learn/iot-cyber-security

4.5.2.2.4 Learning Journey

Also in this case a learning journey is provided that builds on the module and helps in getting extensive knowledge on the topic. The journey is depicted in Figure 26 and provides a closer look to the topic. The target audience are students of Information Systems and Computer Science (Bachelor/Master).

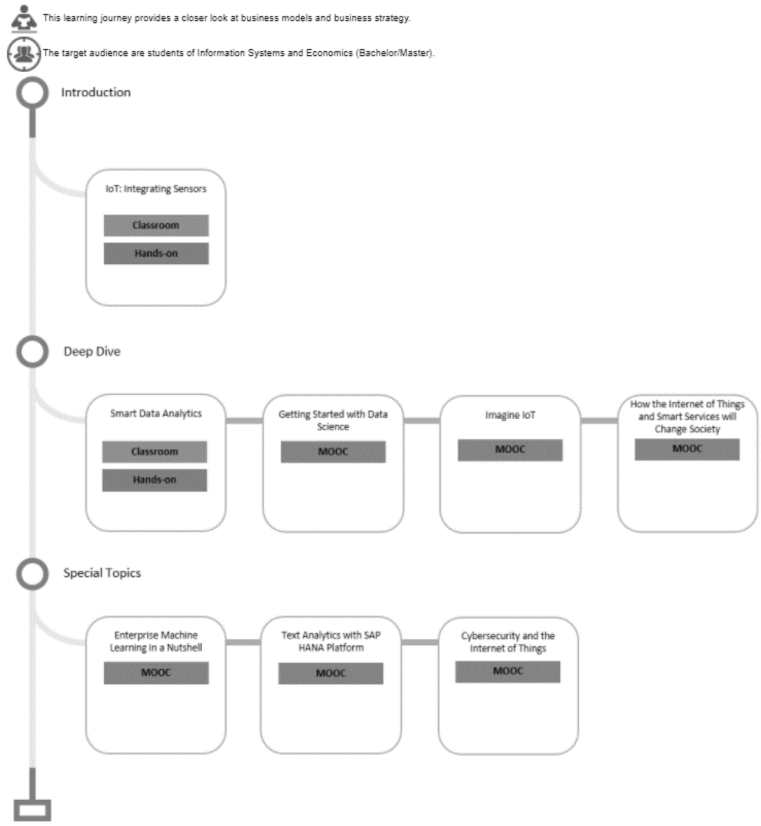

Figure 26: Learning Journey: IoT and Data Analytics (Source: Prifti, Knigge, Löffler, and Banova (2017))

The learning journey starts with an introduction into the topic of IoT: Integrating Sensors that includes the module discussed in this chapter and could be conducted by using the slides and hands-on exercises. This helps in getting an introduction into the topic and technology and creates the necessary prerequisites for going further into the topic. For a deep dive the module of Smart Data Analytics is suggested, which handles further possibilities of analyzing the sensor data with different algorithms and technologies. In the context of deep dive the students can also follow the MOOCs “Getting Started with Data Science[37]”, Imagine IoT” and “How the Internet of Things and Smart Services will Change Society”. For those with a special interest in the topic that want to also gain knowledge in special aspects, MOOCs as “Enterprise Machine Learning in a Nutshell[38]”, “Text Analytics with SAP HANA Platform[39]” and “Cybersecurity and the Internet of Things” are suggested. The learning journey can be used for self-studying

[37] https://open.sap.com/courses/ds1
[38] https://open.sap.com/courses/ml1
[39] https://open.sap.com/courses/hsta1

but also as a whole learning experience in a course and combine class learning and MOOCs in form of blended learning.

4.6 Conclusion

In this chapter a curriculum that aims in transmitting the competencies for the digital transformation towards Industry 4.0 was presented. The curriculum includes 19 modules that can be categorized in 9 sections. Each module includes several learning units. The content of the learning units consist of theory slides, exercises, case studies that can be conducted as group work, hands-on exercises that can be conducted by using the offered software etc. Discussions and questionnaires are provided in each unit in order to make an interactive teaching process possible. Additionally questions at the end of each unit serve as a tool to measure the achieved success. The curriculum can be used by lecturers interested in the topic. It is however not meant to be conducted from one lecturer, in one class in one semester. Moreover it offers content to relevant topics of the digital transformation towards Industry 4.0. Lecturers can mix and match this content and use it in their course. The delivered modules aim the target group of this thesis that includes students of the disciplines of IS, CS, and Engineering.

The curriculum is delivered in form of an HTML application that makes it possible to easily navigate through the content and offer also additional possibilities and tools. A course calculator offers the lecturers the possibility to choose the materials they want. Supporting tools as abbreviation list and glossary help for a fast overview. For each topic a collection of links to relevant MOOCs is also provided in case that the users of the curriculum want to expand they knowledge on the topic. For specific topics of interest, learning journeys are suggested. They include a collection of materials developed during the curriculum as well as online available MOOCs to a topic. By completing a journey a high level of expertise is achieved at the topic at hand.

This curriculum is a first contribution to the community in this area. It covers a wide range of topics, all relevant to the digital transformation towards Industry 4.0. In this way it gives a good overview and offers the possibility to get introduced to the issue. Special curricula to each special topic e.g. the topics of the modules presented in the curriculum could be developed.

5 Curriculum Evaluation

5.1 Introduction

The continuous improvement and quality assurance are important steps of the learning process and competency-based curriculum development. Therefore the evaluation is conducted as the last step of the curriculum development process in order to determine the success of a curriculum (O'Dowd & Gregory., 2002).

In the process oriented curriculum development approaches recommended from Flechsig (1973), Wilbers and Wittmann (2013) or Jenert (2012) the last step of the development is the evaluation of the curriculum. The constructive alignment e.g. Biggs (2003) and Biggs (2014) is also finalized with student assessment and evaluation by offering methods for this purpose. Also further evaluation approaches suggest the evaluation and assessment of learning, as the last step of curriculum development, e.g. the four steps approach described by researchers as Giles et al. (1942), Tyler (1975) as well as Kerr and Berman (1968), the approach suggested by Nicholls and Nicholls (1978) and Wheeler (1978), the six steps approach suggested by Kern et al. (1998), the seven steps approach by Taba (1962), three steps approach by Halaman (2016) and Grayson (1978), SPICES by Harden et al. (1984), integrative approach by Khan and Law (2015), discursive curriculum development by Gerholz and Sloane (2016) etc. All the mentioned methods follow different approaches for developing a curriculum, however they all agree to the importance of evaluation and include this always as the last step of the development.

Many academic institutions also conduct curriculum evaluation. Some institutions perform the evaluation to assure that the topics covered in the curriculum correspond to the demands of the industry, like described by Snoke and Underwood (2002). Another reason for curriculum evaluation may be to find out whether the constantly evolving Information Systems curricula keep their relevance and vitality, e.g., as described by Hill and Chidambaram (2002). Keeping up with the changing demands can be very difficult, and thus gathering student feedback with regards to the presented skills and the overall satisfaction with the course is essential for curriculum improvements (Kurnia, 2007). Another aspect of the importance of curriculum evaluation has been expressed by Chen, Balijepally, and Sutanto (2008). According to the authors, a lack of knowledge about how does the social-networking generation perform learning can be an obstacle in educating them. That is why curriculum evaluation plays a crucial role in university education and should be addressed accordingly.

In the context of competency-based curriculum development as described in this thesis, evaluation plays a crucial role. Schaper et al. (2012) suggest the following points to be considered for the evaluation:

- Competency-based teaching needs to be continuously improved. Therefore it is necessary to apply evaluation and quality assurance instruments.

- It is important to set the competencies at the centrum of the evaluation and developing adapted concepts for the evaluation based on the competencies and learning outcomes.
- Experience shows that by applying evaluation helps in improving the curricula and teaching overall.
- There are different approaches that can be applied for the evaluation:
    - Self-assessment procedure,
    - Questionnaires for the assessment of the competency-oriented learning activities
    - Objective competency tests.
- Evaluation should be set as a scope of the curriculum and be a part of it in order to assure the quality and help in the continuous improvement of the curriculum. (Schaper et al., 2012)

In this thesis a new curriculum was developed that addresses challenges and topics of the digital transformation towards Industry 4.0. The curriculum offers a new approach therefore it needs a careful evaluation since the topics are new and there is no solid experience in teaching them.

5.2 Evaluation Approach

In the context of this thesis a curriculum evaluation on different levels was followed. While rolling out a competency-based curriculum, Schaper et al. (2012) recommend in piloting it first in order to test it and its impact and be able to further improve the learning units if necessary. Afterwards they recommend in developing instruments that are adapted and suitable to be used with the curriculum at hand. By following this suggestions and aiming a holistic evaluation the following four steps with regards to the evaluation were followed:

- **Evaluation Model:** In the context of this curriculum development, a holistic evaluation model was developed. The evaluation model serves as a tool that can be applied in each module or learning unit of the curriculum. It serves as a tool to help the lecturers if they want to evaluate their courses by suggesting the aspects to evaluate and possible questions from the literature. It was developed based on the success factors for IS curricula and existing evaluation models.
- **Pilot Evaluation:** Two months before finalizing the curriculum, a first release including a considerable part of the final modules and learning units was released. This was piloted with a selected group of pilot lecturers. They were then asked with regards to their opinion by using a web survey with opened questions and closed questions with a Likert Scala (Likert, 1932). The results from this step were then applied to improve the final curriculum.
- **Final Prototype Evaluation:** The final curriculum was presented and evaluated with a group of experts: lecturers applying these teaching concepts in class and intending to use the curriculum. Podium discussion were conducted with the lecturers in order to gather their opinions which were then taken into consideration for a further improvement of the curriculum.
- **Evaluation of Single Learning Units:** In order to evaluate the prototype with the biggest stakeholder group, an evaluation with students was conducted. It is not possible to

evaluate every single module with students however some learning units were picked and applied in class, where the students could evaluate them.

5.3 Evaluation Model

For the purpose of this thesis a curriculum is defined as “a collection of documents aiming in delivering a structured series of learning experiences that includes theoretical and practical content to deliver predefined competencies to the learner” (see 2.2.3 Curriculum Concept in the Context of this Thesis)

Many authors agree that curriculum evaluation is an important concept. Curriculum evaluation is defined e.g. as “a study that is designed and conducted to assist some audience to judge and improve the worth of some educational object” (Subah, 1986). White (1971), implies that evaluation is “a phase in the process of constructing and reconstructing curricula. Its purpose is to see whether curriculum objectives are being, or have been, achieved - so that modifications in them can be made if necessary.” In the context of his study, evaluation is defined as a process of collecting feedback about different aspects of the curriculum from the relevant stakeholders in order to assure the goal fulfillment and to identify the improvement potential.

In order to address the evaluation various authors has defined evaluation models. Evaluation models are used for assessing the level and quality of a curriculum (Prifti, Levkovskyi, Knigge, & Krcmar, 2018). Stufflebeam and Coryn (2014) define an evaluation model as “[...] idealized conceptualization for conducting program evaluations”. An evaluation model addresses spatial and structural aspects of the learning process, characteristics of the event (Braun, Gusy, Leidner, & Hannover, 2008) or the output of the curricula (Schaper et al., 2012).

The offered models are however often rather generic and universal and could be applied across disciplines (Stufflebeam & Coryn, 2014) or focus on a very certain aspect (e.g. Escudeiro and Escudeiro (2012)). “While we agree that university learning is a cognitive process and people often learn in a very similar way independently from the discipline, we think that there are some differences through the disciplines in how the learning process is organized and conducted. This is especially true for interdisciplinary areas as Information Systems (IS), where a combination of Computer Science and Economics happens. University curricula in IS have specific requirements, since the discipline combines two areas of studies and includes a broad spectrum of teamwork, technical as well as theoretical learning events. Therefore, the presented evaluation models are not suitable for the discipline of IS (Braun et al., 2008; Snoke & Underwood, 2002).” (Prifti, Levkovskyi, et al., 2018)

Therefore it is important to offer an evaluation approach that is suitable to the characteristics and needs of IS. By conducting a literature review the success factors of IS curricula are extracted. Based on these results, existing evaluation models for curricula are combined and extended in order to offer an evaluation model for IS curricula. (Prifti, Levkovskyi, et al., 2018)

5.3.1 Background

Martínez-Caro, Cegarra-Navarro, and Cepeda-Carrión (2015) describe an evaluation model that has a broad scope and may be applied in various disciplines. The model is developed based on a literature search and focuses on assessing the student's satisfaction in the context of the curriculum. Therefore they define four dimensions: student-student interaction, student-teacher interaction, content, and system flexibility and convenience. Additionally the authors offer also a questionnaire that can be used for each dimension in order to access student satisfaction. While this model offers a good basis to measure the student satisfaction, it is limited to that and do not take any other curriculum criteria into consideration (Prifti, Levkovskyi, et al., 2018).

Alghazzawi and Fardoun (2014) describe an evaluation model that focuses on measuring the student's outcomes. The evaluation model has been used in IS context and proposes to apply exam questions that are each mapped to a learning outcome. In this way it can be measured in what extend each outcome was fulfilled and reached. The model is specific for IS. However it focuses on the specific dimension of the learning outcomes, without taking other factors into consideration (Prifti, Levkovskyi, et al., 2018).

Many other authors propose various evaluation model, by focusing on a certain aspect of the offered curricula. E.g. Wilson and Randall (2012) evaluate a newly designed learning room where the course takes place. Escudeiro and Escudeiro (2012) develop an evaluation model to assess and evaluate learning software used in a curriculum and its application has been shown by Reis and Escudeiro (2014). They address elements as functionality, adaptability, and efficiency of the software and also provide a set of questions for addressing these aspects. These models are as mentioned limited in a certain element that a curriculum may contain and cannot be used to evaluate the whole curriculum (Prifti, Levkovskyi, et al., 2018).

Kirkpatrick and Kirkpatrick (2006) offer a 4-level evaluation that includes: reaction, learning, behavior, and results. "*Reaction* evaluation is aimed at determining how the participants as students, lecturers and other involved stakeholders, feel about the course, and their reactions to it. It is possible to ask them about their satisfaction with every aspect of the curriculum. The second level is *Learning* and the evaluation on this level aims at determining whether the participants have mastered the learning objectives of the course and to what extent did that happen. The third level, *Behavior* aims at understanding, to what extent were the participants capable of applying the knowledge in their job area. The evaluation at final level, *Results*, measures the effect of the training on the environment or business. The effect is captured by the various key performance indicators. This model is very general, it only specifies the four evaluation levels, but it also provides a certain flexibility, by offering the possibility to extend it for specific purposes. For this reason, this model is considered as a basis for this work and is adapted and extended with elements of the other models as well as with success factors in order to serve our purpose in the area of IS." (Prifti, Levkovskyi, et al., 2018)

5.3.2 Method

In order to define success factors for IS curricula a literature review by following the recommendations of vom Brocke et al. (2009) and Webster and Watson (2002) was conducted by searching in major databases as: IEEE, ACM Digital Library, EBSCOHost, AISeL and SpringerLink. This databases offer a good coverage of IS and education literature that may serve as possible outlets for such publications. For the search the query (curriculum OR teaching OR learning OR training in abstract) AND (success in abstract) AND ("Information Systems") was used. “The first two parts of the query included the keywords that should occur in the abstract, because they describe the actual content of the publications that we are looking for, and that is why they should be included in the short summary. For the term “Information Systems”, we have however looked in the whole text, because there are publications that describe the success factors of a course that is taught to IS students, but this is not explicitly mentioned in the abstract, e.g. (Ikonen & Kurhila, 2009). “ (Prifti, Levkovskyi, et al., 2018)

The search process delivered 3290 hits. In a first screening by considering title and abstract and analyzing them for relevance only 79 papers have been considered for the further analysis and synthesis. In a second screening, the complete articles were analyzed and only relevant articles that included success factors for IS curricula were further considered. This step delivered 43 papers that contained statements that can be interpreted as success factors for a curriculum.

Based on the analysis of these papers, 19 success factors for IS curricula were extracted and further combined and categorized and further used to extend the evaluation model of Kirkpatrick and Kirkpatrick (2006). (Prifti, Levkovskyi, et al., 2018)

5.3.3 Success Factors for IS Curricula

From the literature analysis a total of 19 success factors were extracted that are represented in Table 13. (Prifti, Levkovskyi, et al., 2018)

Student Performance (Adroin, 2000; Blount, Abedin, Vatanasakdakul, & Erfani, 2016; Holden, 2008; Karlson, 2001; Larson & Sung, 2009; Mironova, Amitan, Vendelin, Saar, & Rüütmann, 2014; Oeste, Lehmann, Janson, Söllner, & Leimeister, 2015; Rosemann & Maurizio, 2005; Wong & Cheung, 2011; Wu, Guandong, & Kruck, 2014) is one of the most mentioned factors that can be measured e.g. by considering the students grades in a course. A further factor is Mastering of the Learning Objectives of the curriculum (Al-Nory & Igoche, 2012; Ramamurthy, 2016; Wong & Cheung, 2011). It is important that after completing the curriculum the set learning objectives and goals are achieved. Anderson and Krathwohl (2001) define learning objectives as: “[...] both the kind of behavior that has to be developed in a student and the content in which this behavior is to operate” Similar to the learning objectives a further factor includes the Improvement of the Student Skills (Ghosh, Naik, & Li, 2014; Pullan, Drew, & Tucker, 2013; Rumantir, 2007) that is reached e.g. if the students gain the necessary skills to solve problems that they were not able to solve before completing the curriculum. The Enrollment Numbers (Catanio, 2005; Rosemann & Maurizio, 2005)are a further direct success factor that show the interest of the students with regards to the curriculum. (Prifti, Levkovskyi, et al., 2018)

Another success factor is cooperation with external companies and getting feedback from them (Khmelevsky, 2009; Rosemann & Maurizio, 2005), which motivates students in their studies, since they get a perspective from the industry point of view. Feedback should also be gathered from the administration or a faculty, responsible for the curriculum (Maloni, Dembla, & Swaim, 2012; Rosemann & Maurizio, 2005; Simon, 1999) in order to analyze if the curriculum also fulfills the administrative goals of the institution where it is being applied. (Prifti, Levkovskyi, et al., 2018)

Table 13: Success Factors for IS Curriculum
(Source: Prifti, Levkovskyi, et al. (2018))

No	Success Criterion	Explanation
1	Student Performance	The students have achieved the grades with a higher mean than a given threshold.
2	Mastering of the Learning Objectives	The students have achieved the learning objectives, defined before rolling out the curriculum.
3	Improvement of the Student Skills	The students show the better ability to solve the addressed problems after taking the course, than they did before.
4	Enrollment Numbers	The enrollment numbers in the course, where the curriculum is used, are rising.
5	External Feedback	The external partners have fulfilled the goals that they have set for this collaboration.
6	Administrative Feedback	The responsible persons from the university/faculty administration have achieved the goals of teaching the subjects.
7	Student Engagement	Students feel themselves engaged in the learning process and find the course interesting.
8	Content Integrity	The contents of the single learning units fit to one another; the content is well structured in general.
9	Reasonable Workload	The content of the course can be mastered in the specified time.
10	Practical Application	The learned material is applicable in practice.
11	Pedagogical Underpinning	The course provides a deep enough view into its contents.
12	Learning Materials	The materials, like lecture slides, used in learning are understandable and of a good quality.
13	Learning Software	The software used in learning supports the content and helps in applying the gathered knowledge into practice.
14	Lecturer Teaching Skills	The lecturer is capable of delivering knowledge to the students.

No	Success Criterion	Explanation
15	Lecturer Competency	The lecturer masters the subject he teaches.
16	Lecturer Teaching Approach	The lecturer interacts with the students in a way that supports the knowledge transfer and learning process.
17	Hands-on Approach	The students have the ability to apply the learned skills and knowledge.
18	Collaborative Work	The students have the possibility to work with each other by supporting one another in projects and learning improving their social competencies.
19	Student Projects	The projects the students have been working on, delivered a desired outcome.

Student Engagement (Catanio, 2005; Oeste et al., 2015; Pendergast, 2008; Pullan et al., 2013; Rosemann & Maurizio, 2005; Saba, 2012) that can be measured by collecting feedback directly from the students is a factor that is further important for the success of a curriculum since students are the main stakeholders. (Prifti, Levkovskyi, et al., 2018)

Other factors as Content Integrity (Tolhurst & Baker, 2003; Whittington & Nankivell, 2006; Wong & Cheung, 2011) of the curriculum, which describes a well structures curriculum and content, Reasonable Workload (Wong & Cheung, 2011) describing that the content of the course can be mastered in the specified time, Practical Application, meaning that the curriculum content can later be applied later on in praxis (Eom, Gudigantala, & Mitchell, 2015; Liou, Easton, Valacich, & Jankowski, 1995; Rosemann & Maurizio, 2005), and Pedagogical Underpinning, meaning that the curriculum provides a deep enough view in its content (Staikopoulos, O'Keeffe, & Conlan, 2015) were further factors mentioned in the literature. (Prifti, Levkovskyi, et al., 2018)

Furthermore the used materials as The Learning Materials, which are delivered to the students (Maloni et al., 2012; Pullan et al., 2013), and the Learning Software, used in course to support the content (Dickson, 2010; Pullan et al., 2013; Rosemann & Maurizio, 2005; Scholtz, Cilliers, & Calitz, 2012) play a role in the curriculum success. Factors with regards to the lecturer teaching the course play also a role in the curriculum success as Teaching Skills (R. Baker & Papp, 2004; Jewels & Albron, 2009) that describe if a lecturer is capable at transferring knowledge to the students, Competency, describing if a lecturer is competent in the subjects (Davison, Panteli, Hardin, & Fuller, 2017; Rosemann & Maurizio, 2005; Saba, 2012), and the Teaching Approach, describing the way the lecturer interacts with students (Saba, 2012). (Prifti, Levkovskyi, et al., 2018)

The Hands-on Approach (Chayakonvikom, Fuangvut, & Cannell, 2016; Whittington & Nankivell, 2006) that gives the students the possibility to apply the learned knowledge in practice, Collaborative Work (Maloni et al., 2012; Saba, 2012), or group work on Student Projects (Ikonen & Kurhila, 2009; Murphy, 1987) are further factors determining the success of a curriculum in IS: (Prifti, Levkovskyi, et al., 2018)

5.3.4 Development of an IS Evaluation Model

As discussed in 5.3.1 Background the model suggested by Kirkpatrick and Kirkpatrick (2006) was extended with the success factors described above in order to develop an evaluation model for IS curricula. The model is flexible and it can be easily adapted to the purpose in this thesis. For this purpose the two first levels of the model were used: Reaction and Learning. They cover the features of an IS curriculum and make it possible to have a model that is easily applicable. The two remaining levels: Behavior and Results were not used since they are more focused specifically for curricula applied in companies, which is not in the scope of this thesis. (Prifti, Levkovskyi, et al., 2018) The developed model is presented in Figure 27

The defined success factors were clustered and combined with the model defined by Kirkpatrick and Kirkpatrick (2006). Factors as Student Performance, Mastering of the Learning Objectives, and Improvement of the Student Skills can be directly measured and describe the effectiveness of the learning. Therefore they were clustered under the level “Learning” of the model suggested by Kirkpatrick and Kirkpatrick (2006). (Prifti, Levkovskyi, et al., 2018)

Content Integrity, Reasonable Workload, Practical Application, and Pedagogical Underpinning are all factors related to the content of a curriculum, therefore they were grouped together under Content. Learning Materials and Learning Software are elements describing the learning environment, therefore they were grouped under “Environment”. Lecturer related success factors as Lecturer Teaching Skills, Lecturer Competency, and Lecturer Teaching Approach can be grouped under the “Lecturer” category. While Hands-on Approach, Collaborative Work, and Student Projects are grouped as “Learning Method”. Student Engagement and Enrollment Numbers can be considered as factors related to the motivation of the students and are grouped under “Students’ Motivation”. While the feedback related criteria as External Feedback and Administrative Feedback are grouped as “Stakeholder Feedback”. (Prifti, Levkovskyi, et al., 2018)

All the elements of the created groups or categories as: “Content”, “Environment”, “Lecturer”, “Learning Method”, “Students’ Motivation” and “Stakeholder Feedback” describe how the students, lecturers or third parties feel about the curriculum and their overall satisfaction with the curriculum and its content. Therefore, based on the model suggested by Kirkpatrick and Kirkpatrick (2006), they can be categorized in the level “Results”. (Prifti, Levkovskyi, et al., 2018)

Based on the analyzed literature an evaluation mechanism is proposed for each success factor. To evaluate the curriculum content, the approach suggested by Martínez-Caro et al. (2015) that provides survey questions to explore the Pedagogical Underpinning and the Workload of the course can be applied and extended with the approach from Kirkpatrick and Kirkpatrick (2006) which suggests questions for evaluating Content integrity and Practical Application. Furthermore Martínez-Caro et al. (2015) suggest also questions for evaluating the Learning Materials which can be extended with the Quality Evaluation Framework from Escudeiro and Escudeiro (2012), for the evaluation of the Learning Software, since it allows to perform a full evaluation based on the different criteria.(Prifti, Levkovskyi, et al., 2018)

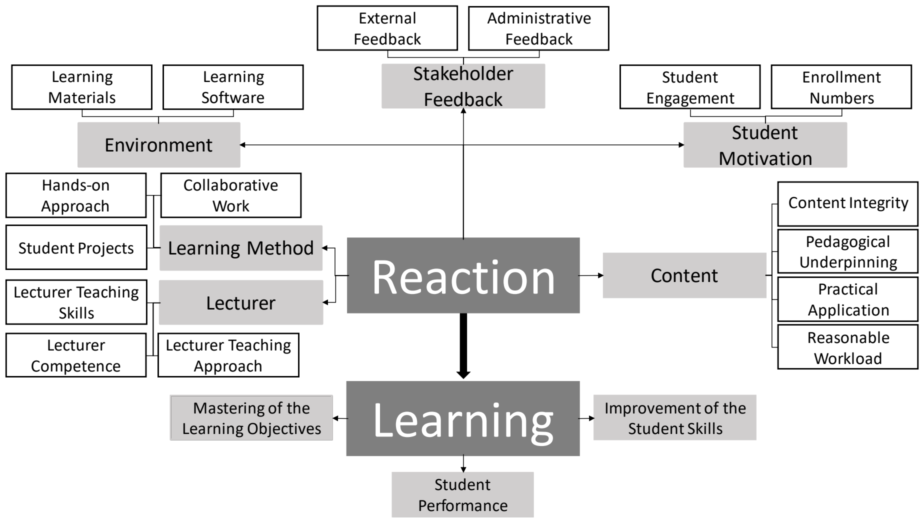

Figure 27: Evaluation Model for IS Curriculum
(Source: Prifti, Knigge, Löffler, and Banova (2017))

To evaluate the lecturers themselves the questions from Martínez-Caro et al. (2015) to evaluate the Lecturer Teaching Approach and Teaching Skills can be combined with the survey questions from Kirkpatrick and Kirkpatrick (2006) in order to evaluate the Lecturer Competency. Martínez-Caro et al. (2015) also provide questions for evaluating the Collaborative Work and Student Engagement while Kirkpatrick and Kirkpatrick (2006) provides further ones for evaluating the Hands-on Approach and the Student Projects as well as External Feedback and the Administrative feedback. (Prifti, Levkovskyi, et al., 2018)

Alghazzawi and Fardoun (2014) suggest in mapping the exam questions to the learning objectives and the percentage of the students that have answered the questions correctly can be analyzed for measuring the Mastering of the Learning Objectives. The same approach can be followed for the evaluation of the Improvement of Student Skills. (Prifti, Levkovskyi, et al., 2018)

„The proposed model can be applied by academic institutions that teach in the IS area to evaluate their curricula. The lecturers can choose which success factors they want to evaluate and adapt the model and suggested evaluation mechanism for their own purpose. E.g. If a curriculum does not include any group work or collaboration, that part of the model can be removed and the other factors can be evaluated.

While there have been many studies on evaluation approaches over the years, there is no contribution that addresses the evaluation needs of the IS discipline, which is an interdisciplinary area that has special requirements concerning curriculum evaluation. Therefore, with this paper, we make a first contribution in this area of study that can be used as a basis for further research. The model can be adapted for special curricula. Furthermore, a practical application of the curriculum in practice could deliver new results.“ (Prifti, Levkovskyi, et al., 2018)

In this context the model can be also applied from lecturers using parts of the developed curriculum for teaching in order to evaluate them. Depending on the content that is being evaluated the lecturers can adapt a suitable tool from the literature.

5.4 Pilot Evaluation

5.4.1 Evaluation Tool

The pilot evaluation was conducted August-September 2017 by using a web survey with questions with regards to different parts of the curriculum. Moss and Hendry (2002) argue that web surveys offer a suitable tool for evaluating curricula. The web survey was designed by using Google Forms[40]. The target group of the survey were lecturers who were aiming at applying the curriculum in their class. In this way, the curriculum was piloted with one of the most important stakeholder's group. The survey starts with a short introduction to the curriculum, it takes 10-15 minutes and is handled anonymously. It contains five sections with questions to different aspects of the curriculum by focusing to only on the content but also on the structure and delivery of the curriculum. It includes closed questions with a five points Likert Scala as well as opened questions where the participating lecturers can express their opinions. The structure of the survey is as follows:

Section 1 – Structure of the curriculum: The curriculum is based on a teaching case approach. It has a modular structure that offers flexibility. Each module contains learning units. In this section the lecturers were asked regarding their opinion in relation with this structure.

Section 2 – Provided Materials: The curriculum includes a large number of materials and combines many teaching approaches by including slide decks, case studies, exercises, hands-on etc. Abbreviations and Glossary are provided as additional tools. In this section the lecturers were asked to evaluate these aspects of the curriculum since this is one of the core deliverables that the curriculum provides.

Section 3 – Provided System: Some of the delivered hands-on exercises are based on an S/4 HANA system. Therefore here the evaluation aims this special aspect of the curriculum – the applied technology. This part was however optional since not all the participants used the S/4 HANA system. So the ones who used it could fill the evaluation.

Section 4 – General: This section provided free text fields in case the participants had further feedback, input or ideas.

Section 5 – Statistical Information: In this section some questions for statistical purposes are provided as: country, experience, courses and degree.

The complete set of questions used in the pilot is provided in Attachment B: Survey for the Pilot Evaluation.

[40] https://www.google.com/forms/about/

5.4.2 Application

The survey was applied to lecturers interested in applying the curriculum in their class. For this purpose the lecturers were addressed in two ways as described below.

Class Evaluation: For the class evaluation a workshop in form of a train the trainer course with the lecturers was offered in September 2017. 20 lecturers with experience in teaching and interested in applying the curriculum in class participated. The workshop went on for five full days and eight hours a day. A selection of the modules and learning units was offered in the workshop including:

- Strategy and Business Model Innovation
- Business Change Management
- Enabling Technologies and Interfaces
- Introduction to S/4HANA and Fiori UX
- Materials Management
- Sales and Distribution
- Production Planning
- Enterprise Asset Management
- Finance and Controlling

The workshop was conducted and moderated by an experienced lecturer and co-author of the curriculum. The topics above were handled in the workshop similarly as they would be handled by a lecturer in class. However the lecturers had also the opportunity to discuss the concepts being taught and suggest their ideas. At the end of the fifth day, after participating to the workshop, the lecturers were requested to fill the web survey and give their opinion about the curriculum and the different aspects of it.

Virtual Evaluation: In August 2017, 32 lecturers showed their interest in participating in this evaluation. They received the curriculum pilot and had a total of eight weeks to analyze it and also apply it in class if desired. Two weeks after the curriculum was sent, the evaluation was sent to the lecturers in order for them to fill it and give their feedback. In order to cover a larger number of feedback in the survey, a total of three reminders over the period of time were sent.

In this way there was a total of 52 participating lecturers in the pilot evaluation. They could either choose to test it by themselves, test it in class with students or be active participants of the workshop. In this way it can be assured that many opinions are gathered and lecturers are evaluating the curriculum from different perspectives.

5.4.3 Results

A total of 52 lecturers received the link to the survey and had the chance to submit their opinion 11 of which took part which makes a 21% participating rate. Further evaluations of the complete concepts are conducted in the following steps. Below the results of the evaluation for each section will be presented and discussed.

5.4.3.1 Section 1 – Structure of the curriculum

Transformation from Global Bike to "GBS": The participants rated the fact of sticking to the well-known Global Bike story as very good with an average of 4,5 points on the Likert Scala (Likert, 1932). While the teaching case approach was rated with 4,1 points (Figure 28). This was due to the fact that one participant gave a very low point to the question. However the participants liked the construct: *"I like the modular approach"*, *"I like it because students will get a transparent and more holistic insight into future upcoming issues concerning Digital Transformation for a manufacturing company. By the contents of the different presentations studies get the main ideas for playfully performing practical scenarios with simultaneous building up of profound knowledge about the topic Digital Transformation as a whole. All contributors have done a great job."* As an improvement the participants suggested bringing more hands-on exercises, e.g. *"I wish there was more practical curriculum (using SAP S/4HANA or SAP ERP) but understand it is still under development".* The point was addressed in the final release of the curriculum where more hands-on exercises were added. Including exercises in HANA and S/4 HANA.

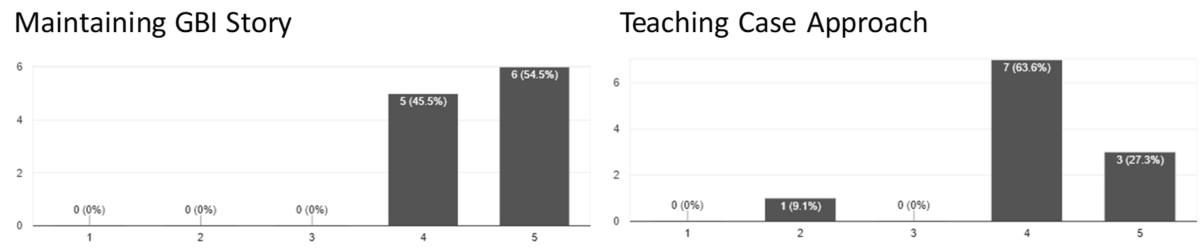

Figure 28: Pilot Survey Results 1
(Source: Own Representation)

Modules: The participants rated the modular structure of the curriculum with almost 4,4 points in average. Linking related content was also rated very high with 4,6 for existing curricula and content, and 4,4 for existing MOOCs on the internet (Figure 29). Regarding missing modules, one participant wrote: *"Most of the modules dealing with S/4 Hana functionality are encapsulated very strictly and seems to barely customizable for own purposes. The combination of these modules to a bigger story, as to showing the integrating aspects of business processes for a central business information system, as S/4 Hana is, seems to be a hard job and almost unrealizable. A module dealing with MRP functionality is missing. When modelling manufacturing companies with S/4 Hana, a 'purchase to pay' scenario of a trading good is obviously not so important than for a raw material, isn't it ?"* The comment has some aspects. First the participant requires more customizable content. While this is a valid suggestion, it is not part of the offered curriculum. The offered curriculum aims in showing the processes of the digital transformation. In the case that a lecturer desires to customize the case studies by himself, other kind of curricula can be taken into consideration that consider the customization aspect. The second part of the comment suggests conducting an MRP. MRP stands for Material requirement Planning, it is a SAP ERP functionality. This is a valid suggestion and can be included in a second release of the curriculum. It the actual scenario of the Global Bike company it does however not play a central role and the goal of the curriculum, is not to cover all the SAP functionalities, but in covering the important topics of the digital transformation. Further comments include: "*I like the idea of a Curriculum with several possibilities for exploitation and providing eventually* *different/diverse points of view, from 3d parties.”* and *“I wish the slideshows would have not been so long. Some slides were shown in more than one module.“* To address the last comment, a general teaching note with a detailed explanation on how to use the curriculum was introduces in the final version. The content is not provided to be conducted as a full course. Moreover the curriculum delivers a collection of materials, theory and practical exercises regarding the topic of the digital transformation towards Industry 4.0. It is provided as a support to the lecturers who can choose the content of their interest and mix and match the slides and exercises as they wish.

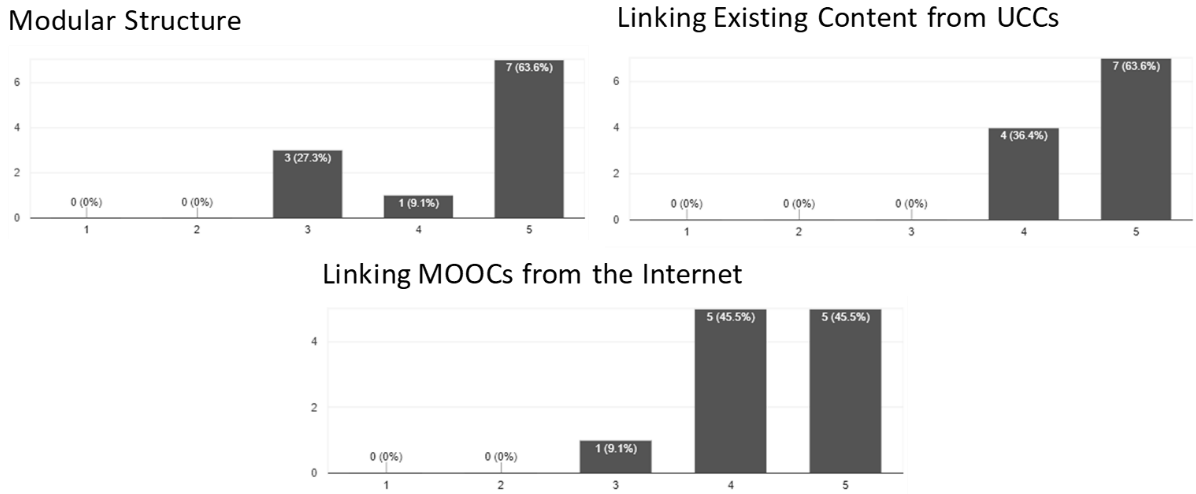

Figure 29: Pilot Survey Results 2
(Source: Own Representation)

Learning Journeys: The learning journeys were rated very good with an average of 4,5 points (Figure 30) on the Likert Scala (Likert, 1932). While most participants did not provide any additional comments, one of the participants suggests to be offered the possibility of a naked system that can be customized. As explained above this is not in the focus of the presented curriculum. With the provided teaching note and explanation on how to use the curriculum it was aimed to give answers to similar questions.

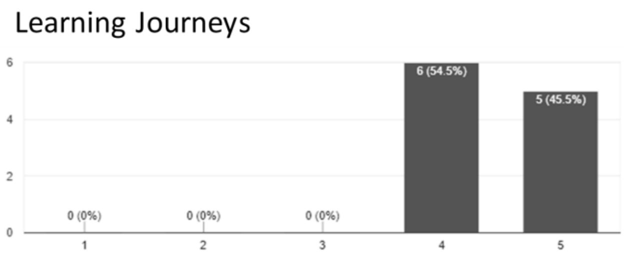

Figure 30: Pilot Survey Results 3
(Source: Own Representation)

HTML Application: The HTML application was rated with 3,9 points regarding the idea and 3,8 points regarding the implementation (Figure 31). As one participant mentions, it is important that the curriculum has a clear structure. It does not make a big difference if it is delivered as HTML or PDF. However in the final version of the HTML additional supporting tools were added as a curriculum calculator, the learning journeys etc. With a classical PDF delivery this would not have been possible.

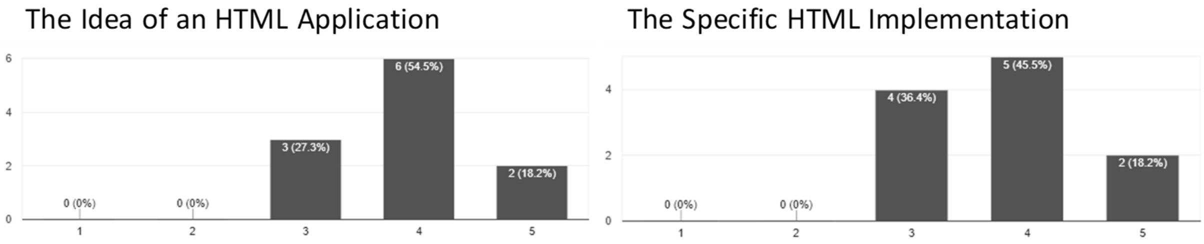

Figure 31: Pilot Survey Results 4
(Source: Own Representation)

5.4.3.2 Section 2 – Provided Materials

Theory: Slide Decks: The participants rated the slide decks with 3,8 points. Although this is a high rate, it was addressed as a critical point and therefore analyzed in detail. One of the reasons for this rating may be that the question is to general and covers all the slide decks. Meaning that somebody that is not satisfied with one of the slide decks may give an overall bad grade. A further fact is also that a limited number of content was delivered in the pilot. This may be a second reason for the rating. One participant argued: *"General comment: The information provided in the slides is not sufficient to teach with them, i.e. the slides are not self-explanatory. Thus I would welcome information on the subject areas and what the message of the slides is. This could be achieved a) by (a limited amount of) background literature b) Podcasts of lectures that apply the teaching with the slides c) teaching notes"*. By taking this comment into consideration additional teaching notes, background literature as well as comments to the slides were provided in the final version.

Further points as competencies were rated with 4,3 points and discussion slides with 3,9 (Figure 32). As an additional comment one lecturer suggests: *"I wish slides with comments (in the Notes area of slides)"*. This comment was addressed accordingly as also explained in above.

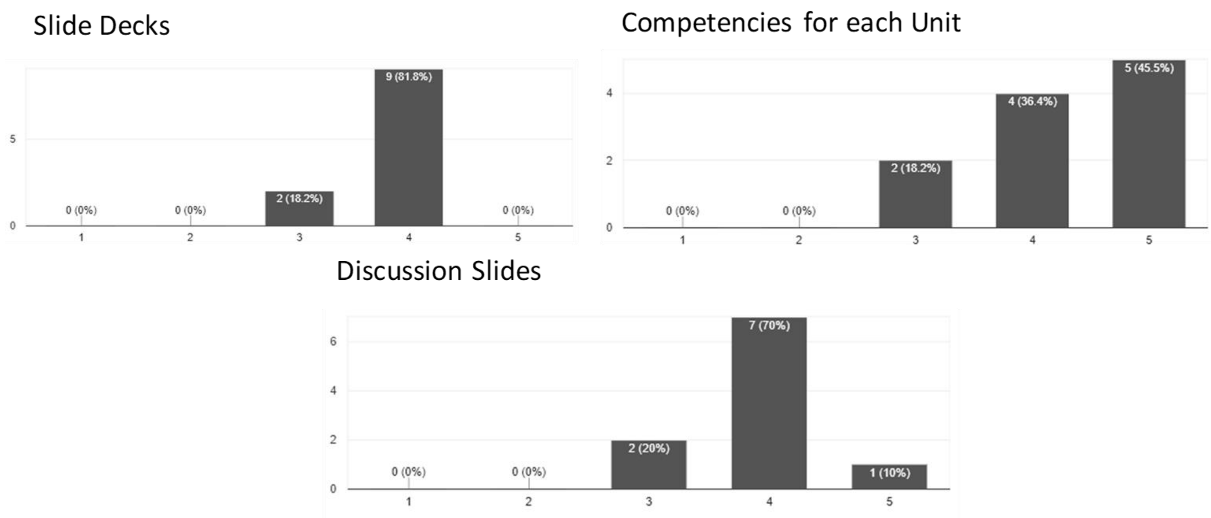

Figure 32: Pilot Survey Results 5

(Source: Own Representation)

Hands-on: Exercises and Case Studies: The rating for this category of questions included: 4,3 points for the case studies, 4,2 points for the interrelation between the slides and case studies, 4,3 for the teaching cases in the case studies and 4,1 for the team/group case studies that include teamwork (Figure 33). This rating is overall very good and reinforces the approach followed in the pilot. One comment included: *"I wish more Hands-On exercises but understand that it´s still under development"*. This was addressed in the final version of the curriculum where hands-on exercises on HANA and S/4 HANA were developed and delivered together with the content.

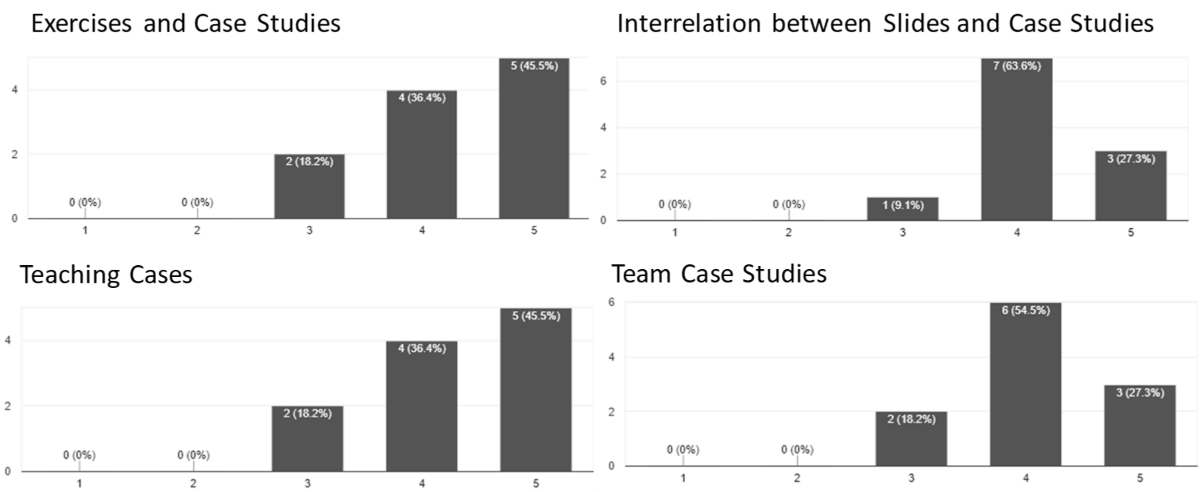

Figure 33: Pilot Survey Results 6

(Source: Own Representation)

List of Abbreviations and Glossary: The list of abbreviations and glossary were rating with accordingly 4,1 and 4,3 points (Figure 34) on the Likert Scala (Likert, 1932), which is a good rating and suggests in maintaining these two elements also in the final version of the curriculum. No additional comments were provided for this questions.

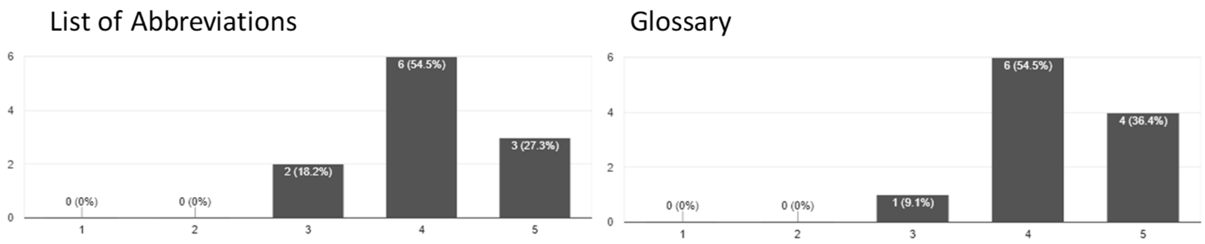

Figure 34: Pilot Survey Results 7
(Source: Own Representation)

5.4.3.3 Section 3 – Provided System

The questions in this section regard the delivered system for testing the hands-on exercises. This is not part of the curriculum therefore does not play a direct role. However the goal is to provide an overall positive experience. Therefore these points were also taken into account. Since not all participants are interested in the hands-on exercises these questions were optional, and therefore responded only by seven participants. The participants rated the system usability with 3,6 points, the system performance with 3,3 points and the Fiori Apps selection with 3,6 points (Figure 35). In order to improve the experience, the performance and usability were improved with the installation of update packages on the system and new Fiori apps were included in the new modules of the curriculum that were delivered in the final version.

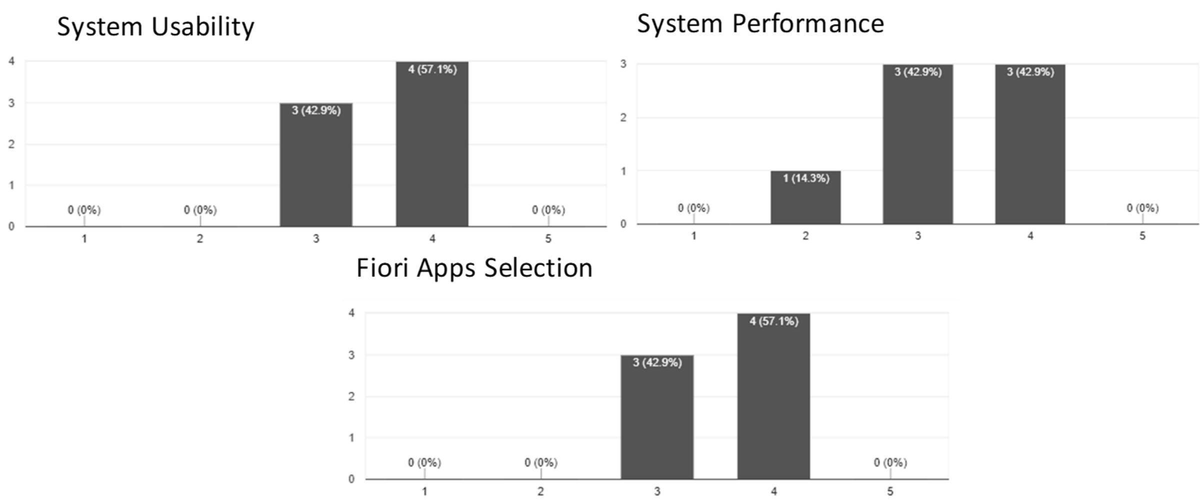

Figure 35: Pilot Survey Results 8
(Source: Own Representation)

5.4.3.4 Section 4 – In General

In the general comment a free text field was available for any additional comment possible. The feedback was very good as one participant mentions: *"I think the Curriculum is very comprehensive - very complete and I struggle to figure out how much time is needed to cover the full program. Typically we have 28 hour modules and I think this would need more time. On the other hand there is still an unbalance between the theoretical part + case studies/exercises AND the system Hands-On (which is still underdeveloped). So the challenge will be how to best* *package all the material and have also sufficient time for Case-studies and S/4HANA Hands-On. But it´s best that we have this "happy problem" than to have few content. Congratulations for all the development already made. I will be looking forward for more guidance on how to best "package" this Program. Kindest Regards"* and another *„Great job! Keep on providing this kind of material ....".*

5.4.3.5 Section 5 – Statistical Information

Most of the participating lecturers (72,7%) are from Germany and have a teaching experience of more than 10 years (72,7%). The higher part of the participants teach at universities of applied sciences in bachelor studies (90,9%). The biggest part is involved in teaching information systems (90,9%). This shows that the participants have an extensive experience in higher education and are mainly from the German education system. This might present a limitation of the evaluation, since most of the participants are from the same background and educational culture.

The evaluation of the pilot presented good results and reinforced the relevance of the curriculum and its contribution. The feedback was positive and some suggestions for further improvement could be collected and were addressed accordingly in the final development.

5.5 Final Prototype Evaluation

5.5.1 Evaluation Tool

For the final prototype evaluation expert discussions in form of a panel discussion were conducted. In the panel discussions a large number of participants is present and can be part of the discussion, however the main discussers sit in the front of the room and lead the discussion with their opinions. The panel discussions do not allow to go into detail into certain modules or learning units, however they give the possibility to have a holistic evaluation of the curriculum concept and approach. This kind of evaluation was aimed at this step, while the detailed evaluation is part of the next step.

In order to conduct the expert discussions it is necessary to prepare an introduction to the topic, therefore some slides with graphics and explanations, presenting the main topics of the curriculum were presented. Afterwards four questions in order to evaluate four aspects of the curriculum were presented and discussed:

- How do you rate the module overview?
- How do you rate the interactive elements?
- How do you rate learning journeys?
- How do you rate course calculator?

Furthermore a survey with the rest of the participants which were not part of the panel was conducted at the end of the discussion. The survey included the following questions:

- *What is your general impression of the new curriculum package?*
  - Modular structure => Flexibility (Likert Scala)
  - Learning Journeys for specific topics (Likert Scala)
  - Curriculum presented in web application (Likert Scala)
  - Course calculator (Likert Scala)
  - Integration of interactive elements (onlineTED) (Likert Scala)
  - Integration of links to related SAP UA content (Likert Scala)
  - Integration of links to external content (MOOCs) (Likert Scala)
- *How do you rate the idea of sticking to the GBI-story and keeping the context for this new curriculum?*
  - Sticking to GBI-story (Likert Scala)
  - New story: GBS as service provider (Likert Scala)
- *Do you miss topics? If so, which? (Free Text)*
- *I like… (Free Text)*
- *I wish… (Free Text)*

5.5.2 Application

The expert discussions were conducted during the SAP Academic Conference 2017 in Karlsruhe, Germany. The Academic Conference gathers every year lecturers and professors interested in teaching and education. In the context of this conference two expert discussion rounds in form of a panel discussion were conducted. Each round included 30-40 participants. In order to frame the discussion four experienced professors as part of the panel were elected in each round. These lecturers were the ones who discussed actively while the other participants were able to be part of the discussion as they wished.

The panel discussions were moderated by three co-authors of the curriculum, with the know-how about each detail of it. At the beginning an introduction with slides was conducted. Afterwards, each of the questions above were discussed through the panel and other participants. Each panel discussion took about one hour. Both panel discussions were recorded. The results were transcribed and analyzed afterwards. The results are presented below.

For the further participants of the sessions that were not active discussers questionnaires as mentioned above were distributed. Lecturers who were interested in giving their opinions could fill in the questionnaires. This questionnaires were also analyzed and are presented below.

5.5.3 Results

5.5.3.1 Panel Discussion

Modules Overview: The general feedback with regards to the modules and the structure of the curriculum was positive. The panel appreciated the provided information and structure in general as well as single aspects of it. A point that was much appreciated was the fact the MOOCs and materials are linked in every part of the curriculum. This helps the lecturers to prepare for their course. *"…I think the most interesting in this program that you made, is that you didn't* *stay closed by using SAP or openSAP learning hub you also put content from other supplier inside and this is also important….”* Also the general approach and concept was appreciated during the discussion *“…this is really life changing. Because now we can communicate the potential of the technology to people…“*. The lecturers also proposed some points as e.g. to provide a quiz that can be conducted at the beginning and the end of the course in order to measure what the students learned.

Interactive Elements: The feedback regarding the interactive elements was positive. *“In my general experience it sums the motivation of the students and students like action participation with a goal.”*, *“This is very useful if you don't overdo it in lecture, they just have to install an app on their smartphone in the very first session once and then only need a code in the lecture“*. Many lecturers also mention in using similar tools and proposed in sharing their experience so that these additional tools can be offered as part of the curriculum: *“We have tried in our university a system that was called Itoken and that was a teacher guided program…”*

Learning Journeys: The learning journeys provide a tool for helping in choosing the material of a curriculum. Most lecturers liked the content*: “learning journeys, very important as an educational method. On the good side what I really like was the classification of your modules as Introduction, Deep Dive and Special Topics. I believe this is very important for a teacher. Knowing which is which, not all modules are good for an introduction.“* Some also mentioned that it is important to have some kind of classification in the learning journeys in order to know for which target group they should be used *“Now my first degree is in mathematics and here we have 19 over n permutation of combining all of these modules, it is practically impossible... Universities are state universities, public so they are not allowed by law to change their curricula... But all these learning journeys are important to have, they are really there for information purposes your metadata might be very helpful in a search factor so again what are your goals I would teach them a little business models followed by business process modelling followed by I don't know systems integration and process … and a bit of Java and the software development lifecycle.“* There were also lecturers that while considering in using the content of the curriculum as an orientation, want to always develop the content themselves: *“Most people would like to create their own courses I don't know anyone who just takes it readymade, but any help is useful. So as a starting it is great ...“*

Course Calculator: The course calculator is a further tool helping in designing the course. The lecturers consider it important not only for designing their own course, but also as a starting point for discussion, while agreeing with colleagues about a course design: *“In fact by using this I can show my colleagues that it is doable to have a plan for a course then implement it and it might even help you as a teacher. So I think this is great.“*

These results show that the delivered concept presents a positive result and is considered helpful from the lecturers, as one of the main stakeholders for the curriculum. During the discussions valuable feedback could be gathered that was partly integrated and implemented directly in the curriculum and partly documented for further improvement in future releases.

5.5.3.2 Survey

The results of the survey showed that the lecturers appreciate and support the developed curriculum. For all the questions asked where a Likert Scala (Likert, 1932) was available the responses were always over 4 points in average (Figure 36), which means that the structure and content of the curriculum provides what the lecturers are requiring. The highest points were achieved for “Sticking to GBI Story” and “New story: GBS as service provider” with an respectively an average of 4,45 and 4,52 points. This shows that building the curriculum on a story and using a well-known story brings advantages since it awakens the interest of the students and keeps them interested in lecture. The lowest points were achieved for “Curriculum presented in web application” and “Course calculator” with 4,07 and 4,09 points in average respectively. The web application and course calculator are tools provided to help the lecturer in searching for materials and putting the course together. The results show that for the lecturers is much more important to keep the students interested than to develop tools helping the lecturers themselves. An overview with all the answers to the questions is provided in Figure 36.

In the section where open answers were required the responses were merely positive and gave some feedback and ideas that could be addressed in the future. E.g. in the section of missing topics some of the answers were “Human Capital Management”, “take care of national specifics” to integrate the content to “Moodle platform”. While the first two points can be addressed in the future, the last one is specific for each institution and cannot be addressed in the context of the curriculum development.

In the section “I like…” the answers varied from answers regarding single features as: “using the story of GBI and develop it”, “course calculator, learning journeys“, “interactive elements, course calculator modular structure ” “navigation website” “modularization”, “integration of new technology” to information regarding the whole curriculum and concept as “all of it”, “New approach. I think it could be used for our international master’s program. We have a lot of students from India”, “this great structured approach to deal with digital transformation in concrete”, “I like the concept of this course” etc.

Also in the section “I wish…” the answers were various. Some answers were of general nature and were not really related to the curriculum as: “Implement something like ERPsim for free for poor German Universities”, “earlier access to new systems / teaching material for own learning and understanding”; “online teaching for trainer?”, “dates for SAP UA trainings for this topic in 2018 asap”, “to collaborate on bike-sharing research”, “buffer to have GBI dataset in TS410Certification”. Some other responders could give concrete answers as “clear instructions for lectures of ERP”, “to have a possibility to download the whole material as a zip file at the moment it is very ridiculous to download the whole material.”. Some of these points directly addressed in the curriculum. E.g. the ZIP download was made available.

In general the curriculum was evaluated as very good. The feedback was very good and appreciative. All the participants are very content with the single elements, as course calculator, learning journeys, interactive elements. As well as with the while curriculum concept, the story line, construct, offered material and so on. In the future there are some smaller suggestions to be considered. From one side e.g. HCM or more finance case studies are required. Also small functionalities as download over the portal and so on would be a good addition to the curriculum as suggested from the lecturers that might be considered in the second release.

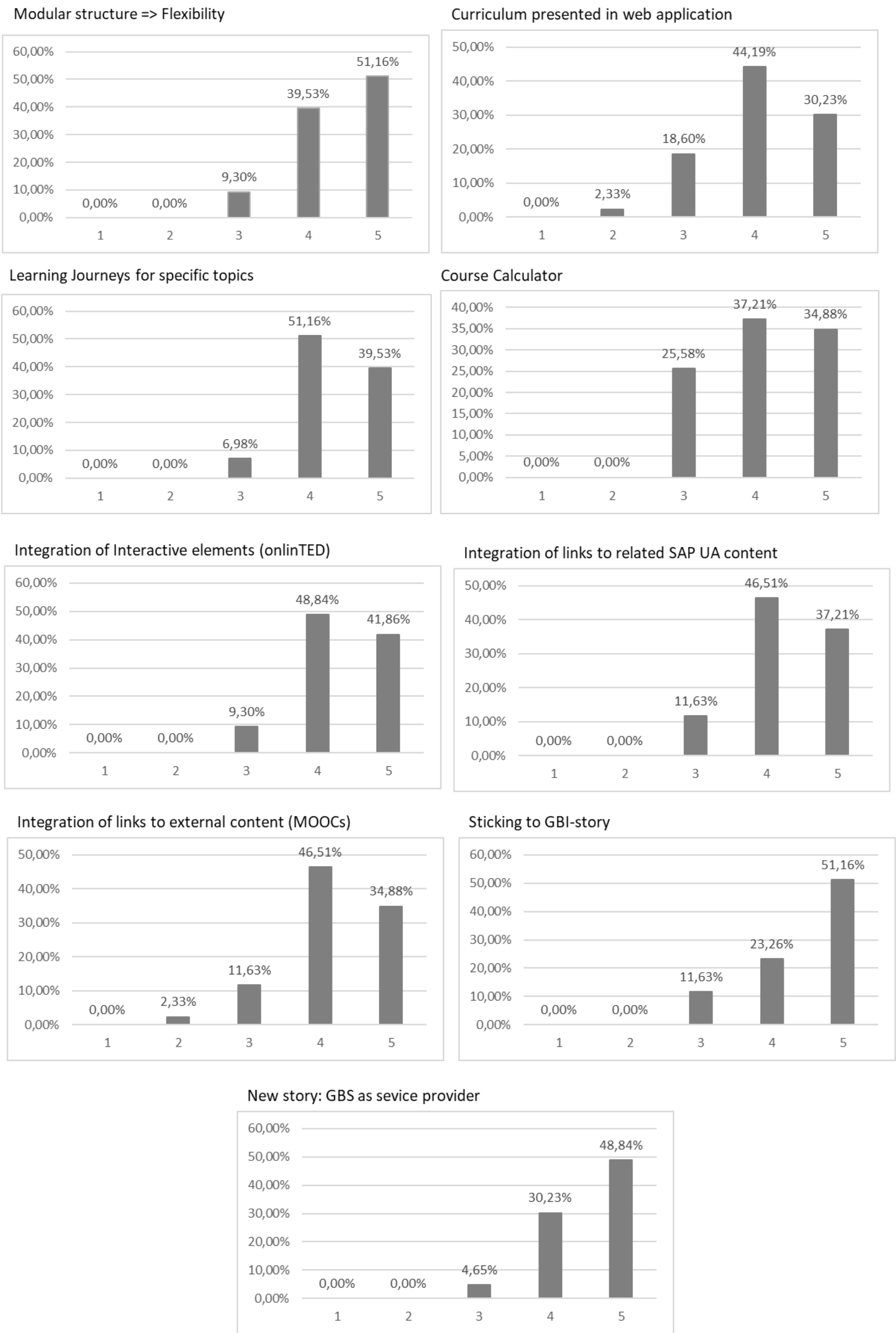

Figure 36: Evaluation Results
(Source: Own Representation)

5.6 Evaluation of Single Learning Units

The developed curriculum in the context of this thesis cannot completely be conducted and evaluated in one course, since the variety of materials and topics is wide. In order however to address the quality of the curriculum, three learning units of the module IoT: Integrating Sensors were evaluated as an example. The evaluated learning units are presented in Chapter: 4.5.2.2.3 Structure and Content and include:

- LU 2.4.2: IoT Data Collection with Sensors
- LU 2.4.3: IoT Data Analytics and Reporting with Sensor Data
- LU 2.4.4: IoT Machine Learning with Sensor Data

These three units were chosen for evaluation since they offer a good mix of theory and hands-on exercises.

This step of the evaluation was performed after the module was finalized. Its main goal was to gather insights concerning the following evaluation questions:

- **EQ1:** What is the study and knowledge background of the participants?
- **EQ2:** How well do the learning units reach the determined learning outcomes?
- **EQ3:** How do students rate content and structure of the components?
- **EQ4:** Do students have specific improvement suggestions?
- **EQ5:** Are the estimated time specifications for each learning unit correct?

It was carried out separately per learning unit under consideration of the interdependent prerequisites. To meet realistic teaching conditions as close as possible, the evaluation sessions were designed similar to university lab courses and conducted by research assistants in a computer lab at the Chair for Information Systems at the Technical University of Munich.

For the evaluation, a two-steps approach was applied, meaning that the same survey with questions was distributed both before and after the theoretical and practical part of a session. Moreover, each learning unit was performed and evaluated both by two students performing as a group and one student working by himself. This aimed to verify the meaningfulness of group work in the context of interactive learning. To satisfy EQ5, during each evaluation session the time was captured to verify the time specification for each learning unit.

5.6.1 Evaluation Sessions

In each conducted evaluation session, one learning unit was carried out and evaluated. As mentioned in the previous chapter, the sessions were attended by three participants each, whereby one of them worked on his own and two of them worked together as a group.

At the beginning of each session, a short kick off presentation was given containing an introduction and some basic information about the agenda. Then, the session’s pre-test survey was conducted determining the prior knowledge level and personal information of the participants.

Hereafter, the theory slide set of the learning unit at hand was presented. Following, the practical part was performed in form of the interactive case study. Finally, the session's two different post-test surveys were handed out to the participants depending on if they worked by themselves or in a group.

Attachment C: Evaluation of Learning Units - Agenda provides more detailed information about the single session's agendas and the survey questions distributed in each of the two evaluation steps. A detailed overview of the single survey results is provided in the coming chapters.

5.6.2 Evaluation Tool: Survey

As mentioned in the previous chapter, for each evaluation session three separate surveys were developed. Google Forms was used as an online tool for the survey creation. The structure of the surveys and specific questions, their relation to the evaluation questions and, if available, their reference to certain learning outcomes can be found in Attachment E: Survey Questions for the Learning Unit Evaluation

Because of their close relation to the defined learning outcomes, the survey questions differed depending on the learning unit. Moreover, within the topic *Group Work*, the participants were asked different questions depending on if they worked in a group or by themselves.

For most of the questions to be answered, choices according to the five point Likert scale (Likert, 1932) were provided. This psychometric scale provides the following answer options:

- I strongly agree (5)
- I agree (4)
- Neutral (3)
- I disagree (2)
- I strongly disagree (1).

Moreover, some multi-check-box fields, text fields for specific improvement suggestions and a scale from 1 to 6 for total survey assessment according to the German school grading system were used.

5.6.3 Results

The following presents the results of the evaluation. Each evaluation question is addressed separately.

5.6.3.1 EQ1: What is the Study and Knowledge Background of the Participants?

The target audience for the learning units are students of IS; CS and Engineering on both, the Bachelor and Master levels. Each learning unit evaluation was conducted by three students, studying in different study programs and on different study levels. Figure 37 shows the above-mentioned distribution of the participant's study background.

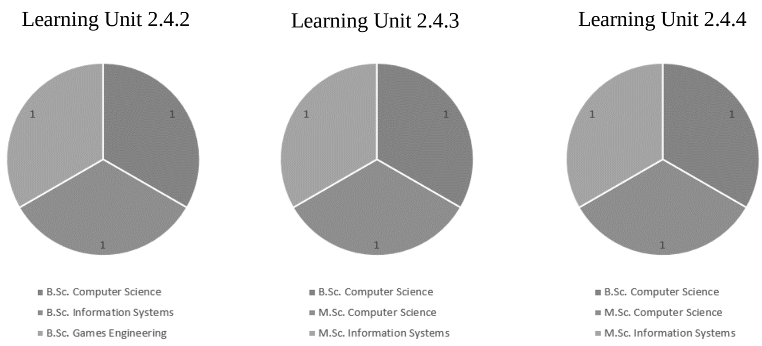

Figure 37: Participant's Study Program Distribution (Source: Own Representation)

In total a good coverage of all three fields was presented, since students with IS, CS as well as Engineering background were part of the evaluation.

Further, to be able to draw meaningful conclusions later on, the students were asked to indicate if they have prior knowledge in the fields of Sensor Technology, Raspberry Pi, SAP HANA / SAP HANA Studio, SAP Lumira, SAP Predictive Analytics or Data Mining / Machine Learning.

Two participants in the first learning unit evaluation stated to have prior knowledge in working with SAP HANA / SAP HANA Studio, while one participant indicated to have experience with SAP Predictive Analytics.

Further, all three participants of second learning unit declared to have prior knowledge in the field of SAP HANA / SAP HANA Studio. Two of them indicated to possess knowledge in the fields SAP Lumira and Data Mining / Machine Learning as well.

All participants of third learning unit evaluation had prior knowledge in the field of Machine Learning / Data Mining. Two of them stated to have experience in the fields of SAP HANA / SAP HANA Studio and SAP Lumira.

All the participants had some basic knowledge on the topics that were being presented. This presents a good prerequisite, since the learning units are not meant for beginners without any previous knowledge.

The outcome of EQ1 is of importance in the interpretation of the results of EQ2.

5.6.3.2 EQ2: How well do the Learning Units Reach the Determined Learning Outcomes?

The survey questions addressing EQ2 were answered by the evaluation participants once before the respective learning unit delivery in the pre-test and once after it in the post-test. Hereby, the main goal was to verify the participant’s competency and skill level change arising from the learning unit delivery by self-assessment. Consequently, the questions to be answered were formulated competency-oriented in order to verify the learning outcomes as presented in Attachment D: Learning Outcomes of the Learning Units. The single questions contained choices according to the five point Likert scale (Likert, 1932).

For the analysis of the survey outcome, the average of all answers on the numerical five point Likert Scala (Likert, 1932) retrieved from the pre-test was compared to the average evolving out of the post-test. A low average value on the numerical Likert Scala means that the participants did not agree with the raised question statement, while a high average value implies the opposite. As the questions were formulated competency-oriented, low average values imply a low competency level, while high average values imply a high competency level in the specific competency area. This approach was chosen, to present the competency level development caused by the learning unity delivery.

Based on these insights, a conclusion was drawn for each of the survey question topics specified in Attachment E: Survey Questions for the Learning Unit Evaluation. The evaluation results were rated as satisfactory, if the post-test average Likert score was at least 4 and an improvement compared to the pre-test could be identified.

This procedure was carried out separately per learning unit[41]:

Learning Outcomes LU 2.4.2: IoT Data Collection with Sensors

Raspberry Pi: Q1.4-Q1.5

As shown in Figure 38, the participants' general understanding of what a Raspberry Pi is and what it can be used for slightly improved (Q1.4: 4 → 4.33) from an already high level. The learning unit reached a significant increase of the competency level in terms of the technical setup of a Raspberry Pi (Q1.5: 1.66 → 4). The high initial score of Q1.4 compared to the low initial score of Q1.5 is not surprising since Q1.5 refers to competencies higher in complexity. Moreover, the low initial score of Q1.5 correlates with the findings of EQ1, where no participant claimed to have prior experience with a Raspberry Pi.

In total, both survey question results indicate a successful achievement of the learning outcomes referenced by Q1.4-Q1.5.

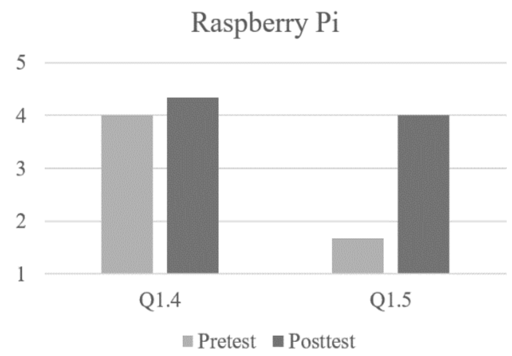

Figure 38: Evaluation of the Survey Questions Concerning the Raspberry Pi (Source: Own Representation)

[41] See the questions provided in Attachment E: Survey Questions for the Learning Unit Evaluation

<u>Sensor Technology: Q1.6-Q1.7</u>

As depicted in Figure 39, the evaluating students agreed to have a quite good general understanding of sensors before the learning unit delivery, which improved even more through the delivery (Q1.6: 4→4.33). In contrast, the knowledge regarding specific sensors and their technical features and characteristics was very limited before the learning unit. This correlates with the findings of EQ1, where no participant claimed to have prior knowledge in Sensor Technology. Nevertheless, through the learning unit delivery it could be significantly raised to a satisfactory level. (Q1.7: 1.66→4.33)

To sum up, both survey question results indicate a successful achievement of the learning outcomes referenced by Q1.6-Q1.7.

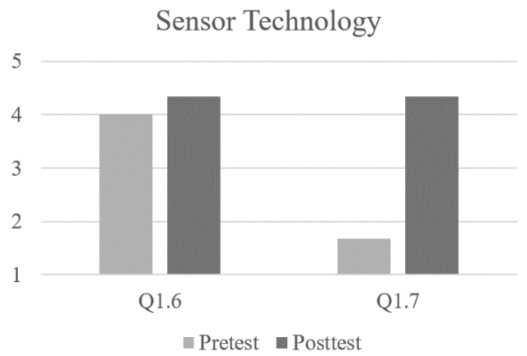

Figure 39: Evaluation of the Survey Questions Concerning Sensor Technology (Source: Own Representation)

<u>Automated Sensor Data Collection: Q1.8-Q1.12</u>

While the students did not seem to have any initial knowledge on the topic addressed by the question category *Automated Sensor Data Collection*, a significant increase of the knowledge level can be noticed caused by the learning unit delivery. Nevertheless, as visualized in Figure 40, the average Likert score did not reach 4 points for any of the five survey questions answered, which must be critically reflected.

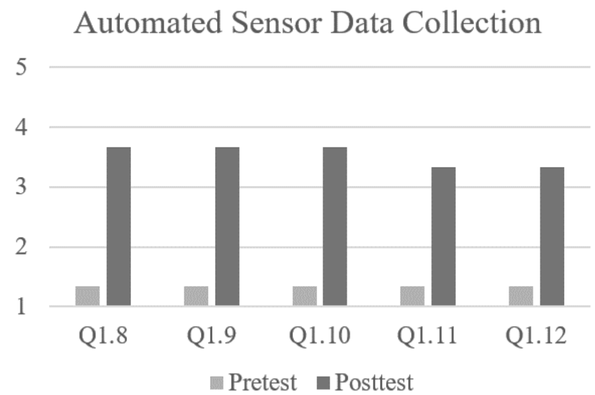

Figure 40: Evaluation of the Survey Questions for Automated Sensor Data Collection (Source: Own Representation)

A possible explanation is the high complexity of the topics. With the prototypical setup of the Raspberry Pi and the two different sensors, the learning unit drifts into the electro-technical area. Participants of the study programs Computer Science, Information Systems and Games Engineering might run into difficulties because of the interdisciplinary nature of the tasks. Additionally, programming in an unfamiliar programming language like Python might be challenging for students in the Bachelor level. At this point it would be helpful to use the proposed MOOCs in order to deepen on the knowledge on the topic.

<u>IoT with SAP HANA: Q1.13-Q1.18</u>

As shown in Figure 41, Q1.13 and Q1.18 both reflect a good initial understanding of the concept of IoT and the advantages of innovative technologies like SAP HANA in this context. Moreover, they show an improvement process (Q1.13: 4→4.33; Q1.18: 3.33→4) on the Likert Scala referencing the competencies imparted by the defined learning outcomes after the learning unit delivery.

The results emerging of Q1.17 indicate no noticeable effect on the student's knowledge-related self-assessment. Hence, the achievement of learning outcome LO1.I referred by this question cannot be proved.

The remaining three survey questions (Q1.14-Q1.16) of this question category show improvement processes regarding the student's competency level in the post-test. Nevertheless, the defined learning outcomes are not met in a satisfactory manner. The learning unit evaluated in this section is the first part of three learning units building upon each other. While this learning unit focusses more on the hardware part of data collection with sensors, the remaining two learning units deal with the utilization of SAP HANA in innovative high-performance IoT solutions. As these are the topics covered by Q1.14 to Q 1.16, this result is acceptable in this case.

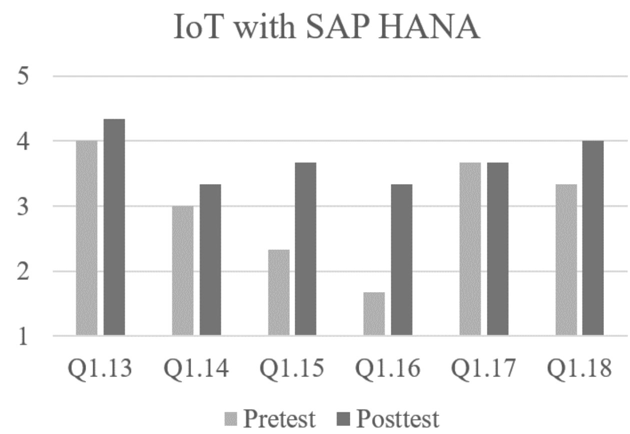

Figure 41: Evaluation of the Survey Questions Concerning IoT with SAP HANA (Source: Own Representation)

Learning Outcomes LU 2.4.3: IoT Data Analytics and Reporting with Sensor Data

Understanding Big Data Sets: Q2.4-Q2.5

Figure 42 shows a high pre-test score for UML-related competencies addressed by Q2.4, which is not a surprise among students in the IT sector. The falling average score (Q2.4: 4→3.66) on a competency-related question points to an incorrect survey input, as already existing competencies cannot disappear in the time interval of a curriculum learning unit. Consequently, this survey question does not provide a reliable result.

Q2.5 indicates the successful achievement of the learning outcomes referenced by this survey question, as the average Likert score raises from an intermediate to a high level (Q2.5: 3→4.33).

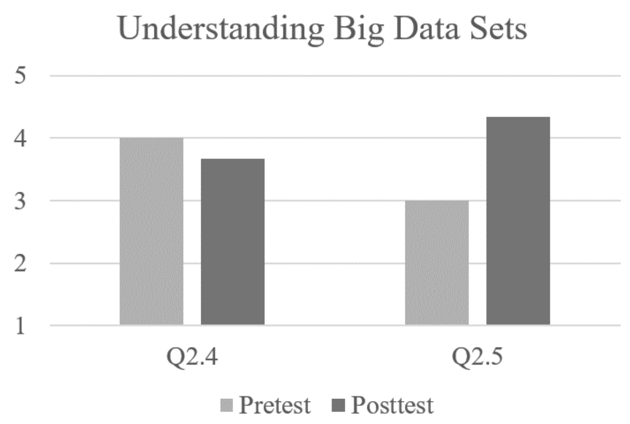

Figure 42: Evaluation of the Survey Questions Concerning Big Data Sets (Source: Own Representation)

Data Modelling: Q2.6-Q2.7

According to survey question Q2.6, the evaluating competency level of the students regarding basic concepts of data modelling was already on an acceptable level before the learning unit delivery. Nevertheless, as depicted in Figure 43, further improvement can be noticed (Q2.6: 4→4.66). This result indicates a successful achievement of the learning outcomes referenced by this survey question.

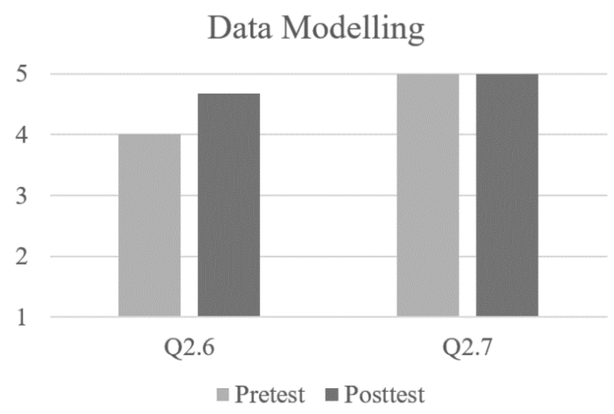

Figure 43: Evaluation of the Survey Questions Concerning Data Modelling (Source: Own Representation)

As the average Likert score of Q2.7 stays on the highest possible level, it is not possible to prove a significant effect caused by the learning unit delivery. This result does not surprise considering the study programs and study levels of the evaluating students pointed out in EQ1.

SAP HANA / Lumira: Q2.8-Q2.12

The evaluation results presented in Figure 44 show that through the learning unit delivery, all average Likert scores of the question category "SAP HANA/Lumira" could be increased from an intermediate to a high level. This proves that the carried-out curriculum learning unit has positive impact on the achievement of the learning outcomes related to the advantages and capabilities of using SAP HANA Studio and SAP Lumira for data modelling and data visualization.

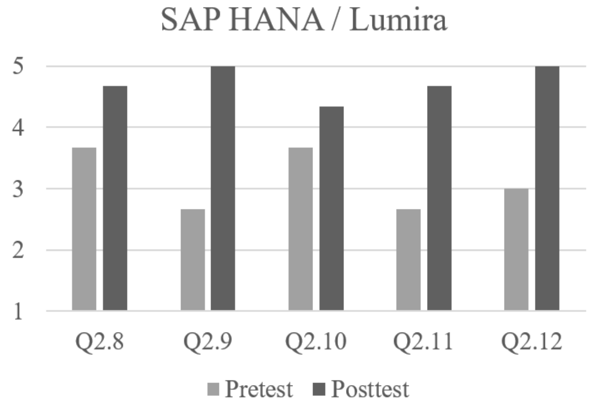

Figure 44: Evaluation of the Survey Questions Concerning SAP HANA / Lumira (Source: Own Representation)

Data Analysis and Reporting in the Business Context: Q2.13-Q2.19

Besides of Q2.19, all survey questions depicted in Figure 45 reach an increase of the average Likert scores from an intermediate to a high level. This implies that the carried-out learning unit meets the defined learning outcomes in the area of data analytics and the interpretation of analytical results in a business context.

As survey question Q2.19 misses to reach a satisfactory skill level, a critical analysis has to be conducted. The survey question is related to the different technologies integrated in a holistic IoT solution, utilizing big data analytics insights. As previously mentioned, the learning unit evaluated in this chapter is the second part of three learning units building upon each other. Despite of the fact that technologies integrated in a holistic IoT solution are subject of this learning unit, this learning unit focusses on data analytics and reporting with SAP HANA and SAP Lumira. Thereby, it achieves good results according to the previous question category. Hence, the achieved score for Q2.19 (2.66→3.66) is acceptable.

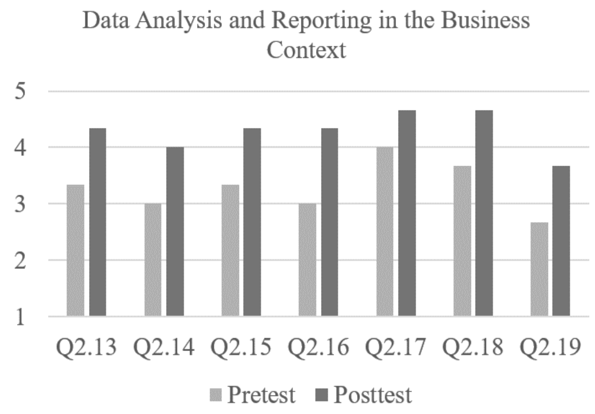

Figure 45: Evaluation of the Survey Questions for Data Analysis and Reporting (Source: Own Representation)

Learning Outcomes LU 2.4.4: IoT Machine Learning with Sensor Data

Understanding Big Data Sets: Q3.4-Q3.5

Both survey questions plotted by Figure 46 show high pre-test average scores. This result does not surprise considering the IT background of the students as well as their study levels pointed out in EQ1. Nevertheless, the slight improvement of the post-test competency level demonstrates that the defined learning outcomes have been reached. Moreover, similar tasks were already performed in LU 2.4.3. As the curriculum module's learning units build upon each other and two of the three evaluating students also worked on LU 2.4.4.

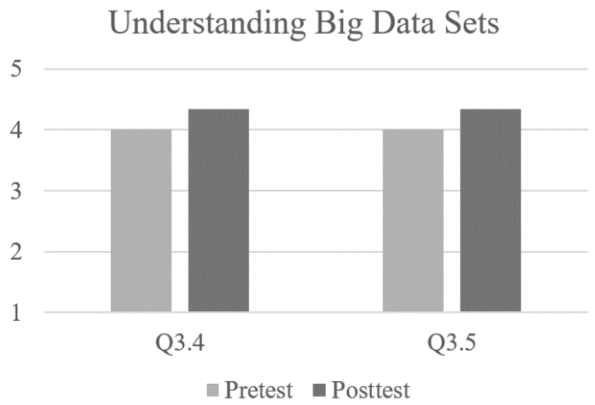

Figure 46: Evaluation of the Survey Questions for Big Data Sets (Source: Own Representation)

Knowledge Discovery Process: Q3.5-Q3.7

Figure 47 visualizes a raise of Q3.6's results from an intermediate to the highest possible average Likert score (3.33→5). Hence, the learning outcomes related to the knowledge discovery process are reached through the learning unit delivery.

As the average Likert score of Q3.7 remains on a high level, it's impossible to verify a significant effect caused by the learning unit delivery.

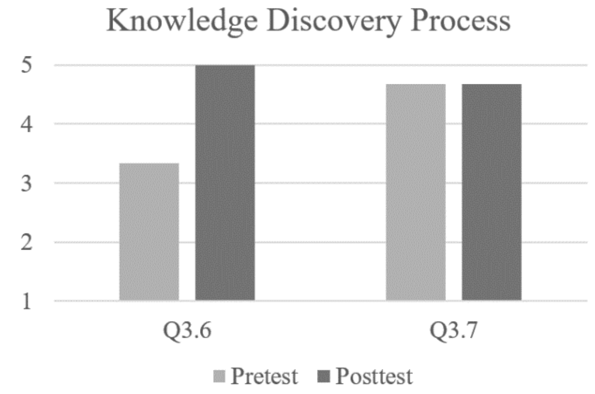

Figure 47: Evaluation of the Survey Questions Concerning Knowledge Discovery (Source: Own Representation)

SAP Predictive Analytics: Q3.8-Q3.11

The determined average Likert scores of the survey questions presented by Figure 48 raised from a low pre-test level to a high post-test level. Hence, this question category shows that the learning unit imparts the most important capabilities and algorithms of SAP Predictive Analytics and the SAP Predictive Analytics library. This indicates a successful achievement of the learning outcomes referenced by these survey questions.

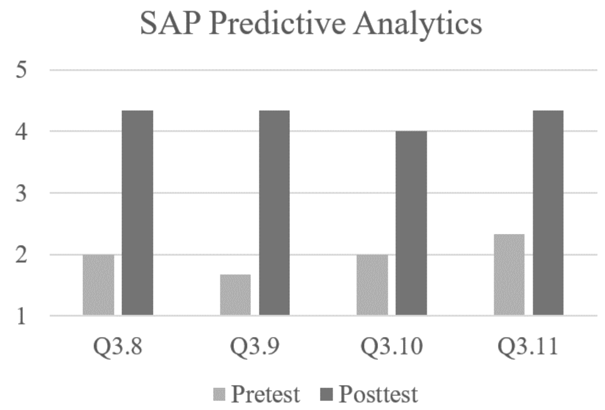

Figure 48: Evaluation of the Survey Questions Concerning SAP Predictive Analytics (Source: Own Representation)

Data Analytics in the Business Context: Q3.12-Q3.17

The question category presented by Figure 49 was meant to verify the achievement of the determined learning outcomes related with analytical topics, like building data mining or machine learning models, interpreting their outcome and utilizing it in customer oriented business models. Besides of Q3.16, all survey questions of this category reach an increase of the average

Likert scores from an intermediate to a high level. This implies that the carried-out learning unit meets the defined learning outcomes in the above-mentioned areas.

As survey question Q3.16 misses to reach a satisfactory competency level, a critical analysis has to be conducted. The survey question is related to the different technologies integrated in a holistic IoT solution utilizing big data analytics insights. As mentioned in the case of Q2.19, the learning unit evaluated in this chapter is the third part of three learning units building upon each other. This learning unit mainly focusses on Data Mining and Machine Learning with SAP Predictive Analytics. Thereby, it achieves good results according to the previous question category. Hence, the achieved score for Q3.16 (2.33→3.66) is acceptable.

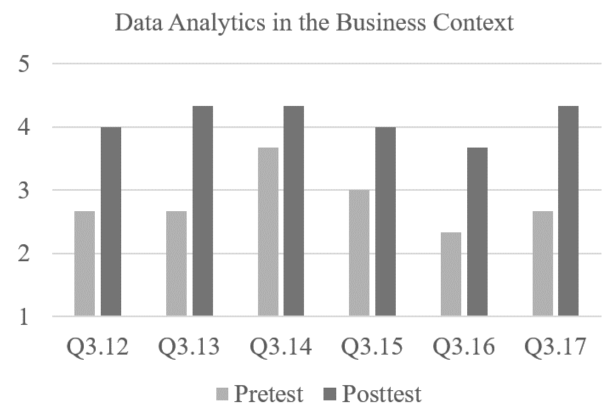

Figure 49: Evaluation of the Survey Questions Concerning Data Analytics (Source: Own Representation)

Group Work Concept

For the evaluation, the three students working on the learning unit case study were split in two groups. While two students worked on the tasks in a group, one student worked on his own. Then, the students were questioned concerning their work preferences and experiences regarding to group work. This question topic aimed to verify the decision to carry out the practical parts in teams of two participants. The following analyzes the survey results separately for the above-mentioned two groups:

Students working by themselves:

100% of the students working by themselves experienced this way of working as productive and helpful (Q1.19, Q2.20, Q3.18). Consequently, as shown by Figure 50, the attitude towards future group work turns out to be neutral (Q1.20, Q2.21, Q3.19).

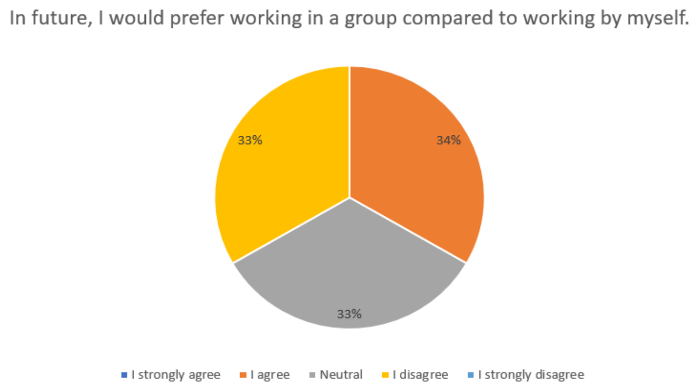

Figure 50: Evaluation of the Survey Question for Working in a Group (Source: Own Representation)

Students working in a group:

On the other hand, Figure 51 shows that 83% of the students working in a group experienced it as productive and helpful (Q Q1.19, Q2.20, Q3.18), while at the same time no student disagreed with this statement.

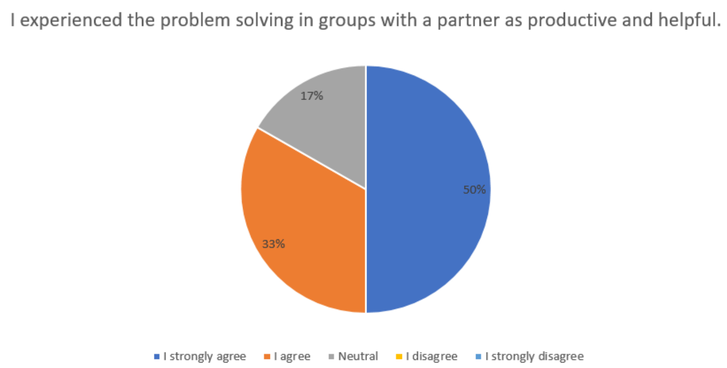

Figure 51: Evaluation of the Survey Question for Working in a Group (Source: Own Representation)

As presented in Figure 52, half of the students strongly disagrees that he would favor working by themselves (Q1.20, Q2.21, Q3.19). Even though also every third participant agrees with that statement, the overall attitude seems to point towards group work.

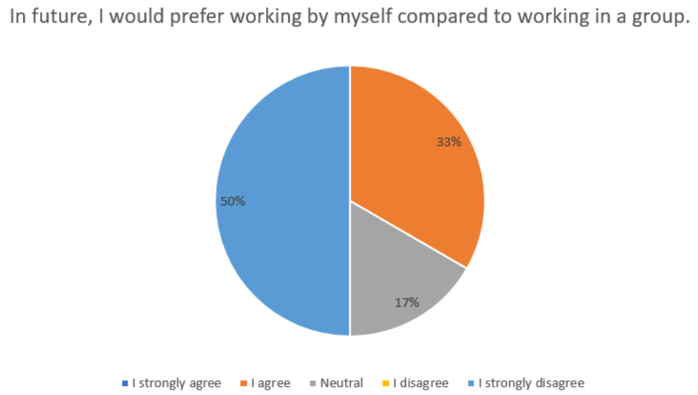

Figure 52: Evaluation of the Survey Question for Working Alone (Source: Own Representation)

Additionally, as plotted in Figure 53, 100% of the students working in a group agreed that the group member contribution for the case study solution was equally distributed (Q1.21, Q2.22, Q3.20).

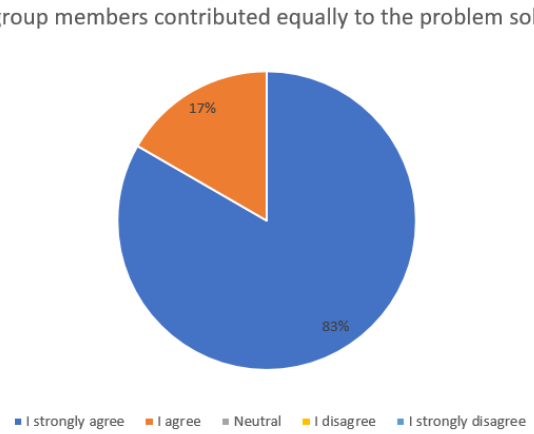

Figure 53: Evaluation of the Survey Question for Group Member Contribution in a Team (Source: Own Representation)

Result:

The answers of the students which worked by themselves are surprising. At the same time, the vote of the students which solved the case study's tasks in a group is clearly positive towards their practice. Further, the fact that the group member contribution to the problem solutions was perceived as equal provides a solid basis for a group-wide achievement of the learning outcomes. To sum up, the evaluation results verify the benefit of the decision to carry out the curriculum module's practical parts in teams of two participants.

5.6.3.3 EQ3: How do Students Rate Content and Structure of the Components?

Theory Slides:

Figure 54 and Figure 56 show that 100% of the curriculum participants agreed or strongly agreed that the presented theoretical part contributed to both the overall understanding of its respective topic and to a successful completion of the learning unit case study. Moreover, Figure 55 demonstrates that at least 67% of the students per learning unit and 78% in total strongly agreed on a clear structure of the theory slides. This constitutes a notably outstanding feedback regarding this curriculum part.

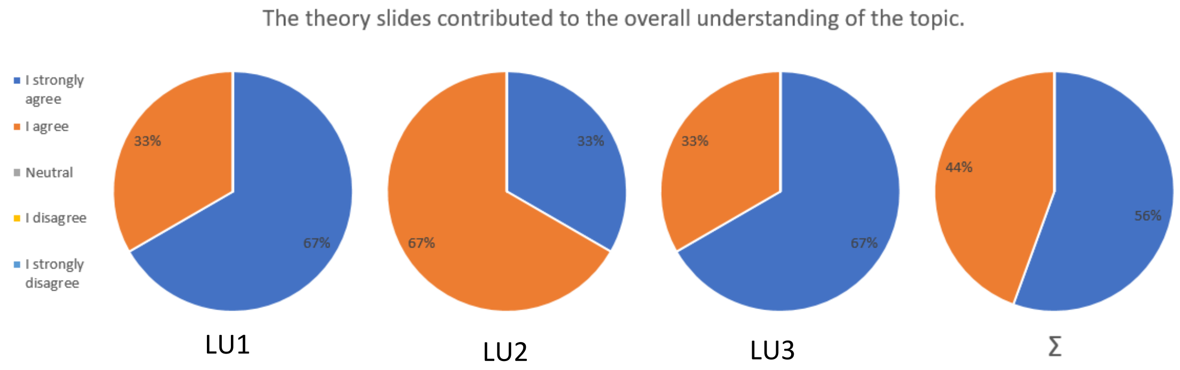

Figure 54: Evaluation of the Survey Questions Q1.22, Q2.23 and Q3.21 (Source: Own Representation)

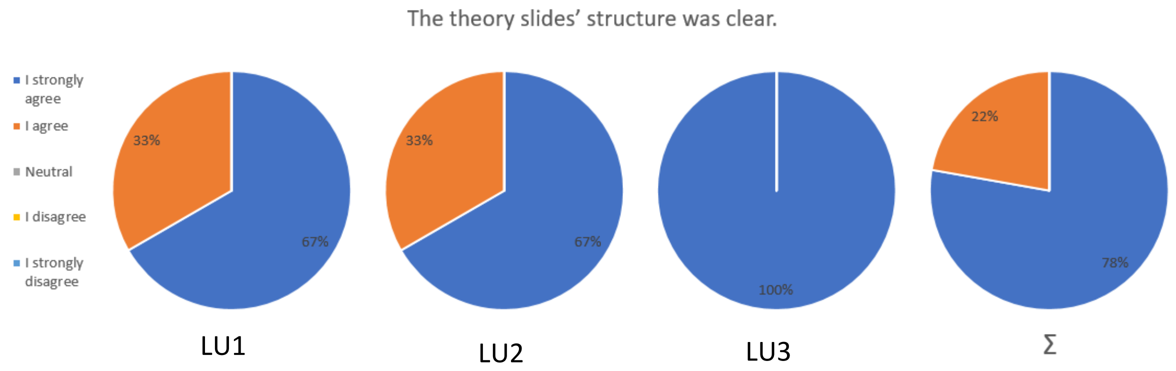

Figure 55: Evaluation of the Survey Questions Q1.23, Q2.24 and Q3.22 (Source: Own Representation)

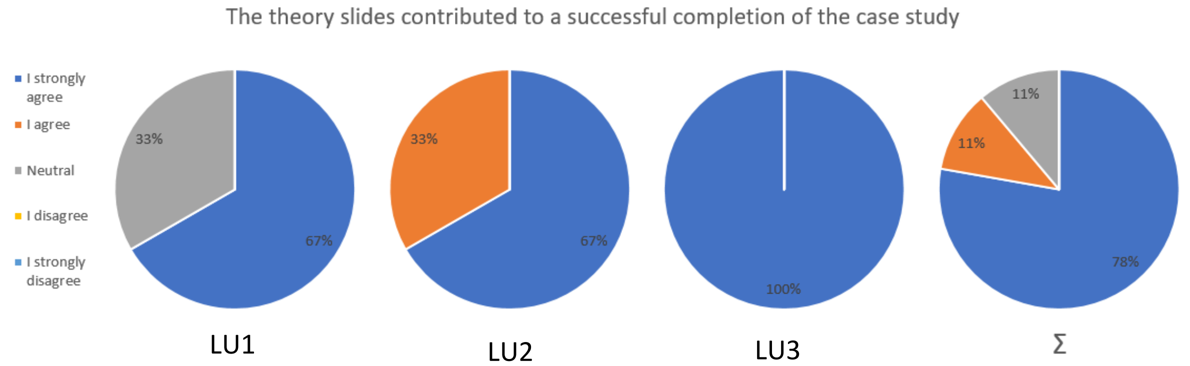

Figure 56: Evaluation of the Survey Questions Q1.24, Q2.25 and Q3.23 (Source: Own Representation)

Case Studies:

As depicted in Figure 57, 89% of the total evaluation participants agreed on an appropriate level of complexity of the case studies. The fact that 33% of the students carrying out LU 2.4.2 had a neutral attitude regarding this evaluation question underline the assumption of the evaluation of Q1.8-Q1.12 that the interdisciplinary challenges and the unfamiliar programming language Python might be challenging for students on the Bachelor level.

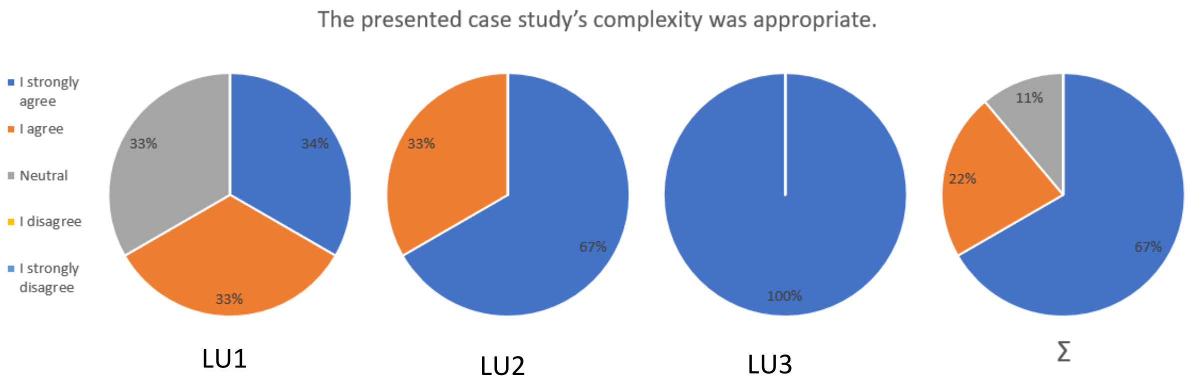

Figure 57: Evaluation of the Survey Questions Q1.26, Q2.27 and Q3.25 (Source: Own Representation)

Figure 58 and Figure 59 outline that in average more than two-third of the participants strongly agreed on realistic and interesting case studies. Further, according to Figure 60, 78% of the attendance agreed that the case studies were suitable for mediating content related to the thesis' topic "IoT: Integrating Sensors into Big Data Analytics".

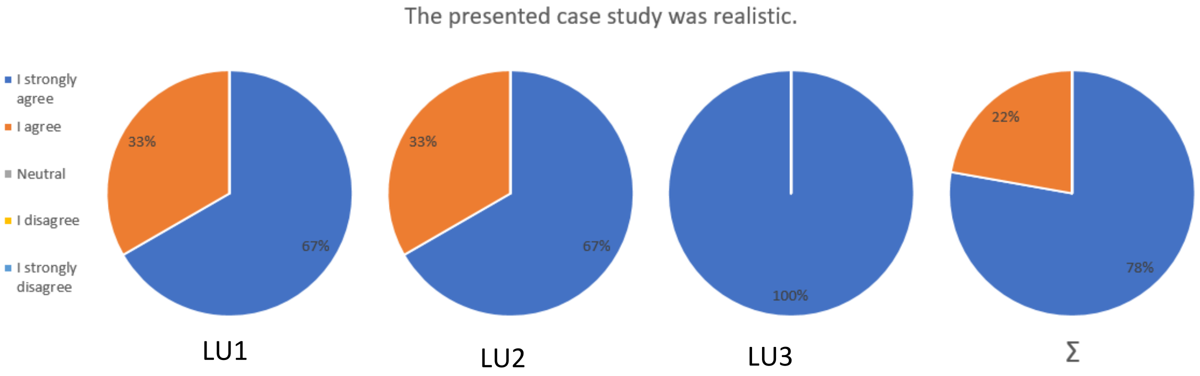

Figure 58: Evaluation of the Survey Questions Q1.27, Q2.28 and Q3.26 (Source: Own Representation)

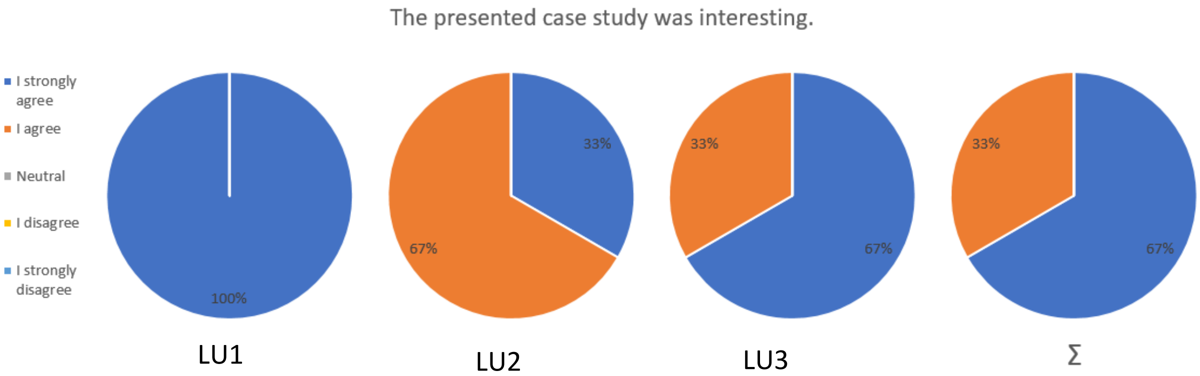

Figure 59: Evaluation of the Survey Questions Q1.28, Q2.29 and Q3.27 (Source: Own Representation)

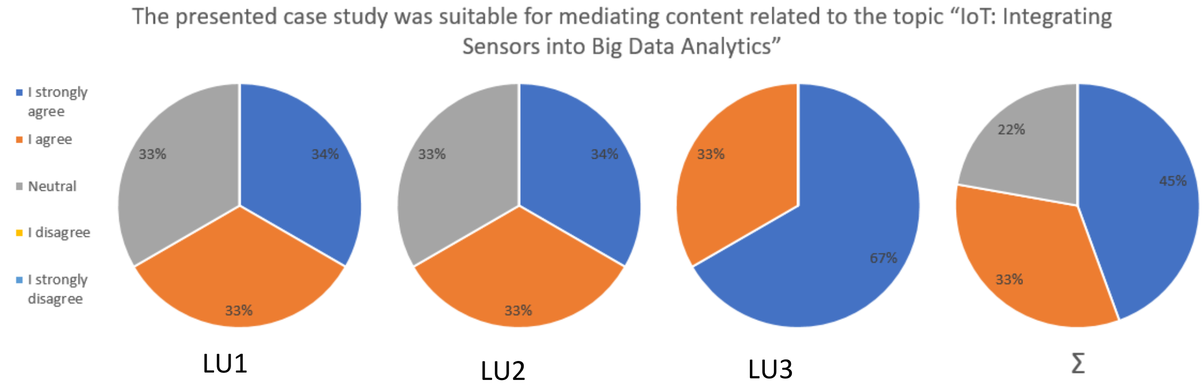

Figure 60: Evaluation of the Survey Questions Q1.29, Q2.30 and Q3.28 (Source: Own Representation)

Figure 61 and Figure 62 present the evaluating students' estimation regarding the case studies' overall structure and their single steps. While at least 67% per learning unit strongly agreed that the respective case study's overall structure was clear, in average 78% of the students were strongly convinced that also the case studies' single steps were clearly arranged. Moreover, as depicted in Figure 63, at least 67% per learning unit agreed or strongly agreed that the single steps' contribution to the respective case study solution was understandable.

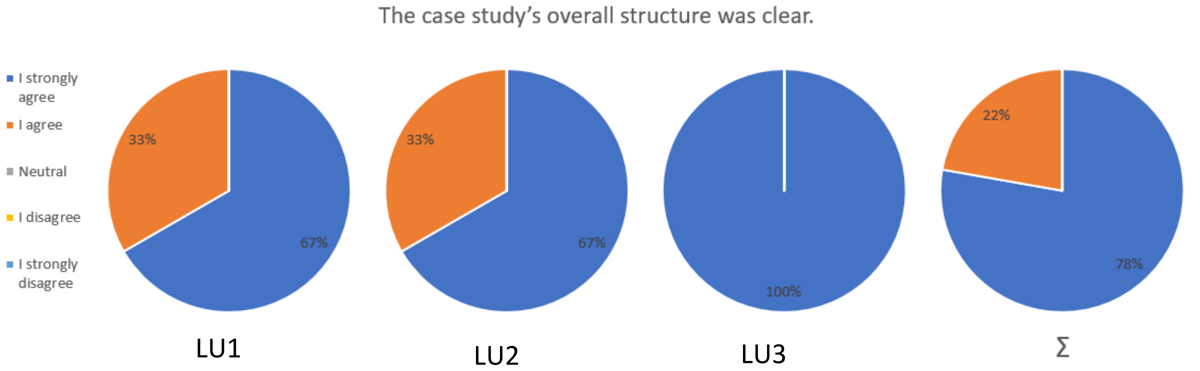

Figure 61: Evaluation of the Survey Questions Q1.30, Q2.31 and Q3.29 (Source: Own Representation)

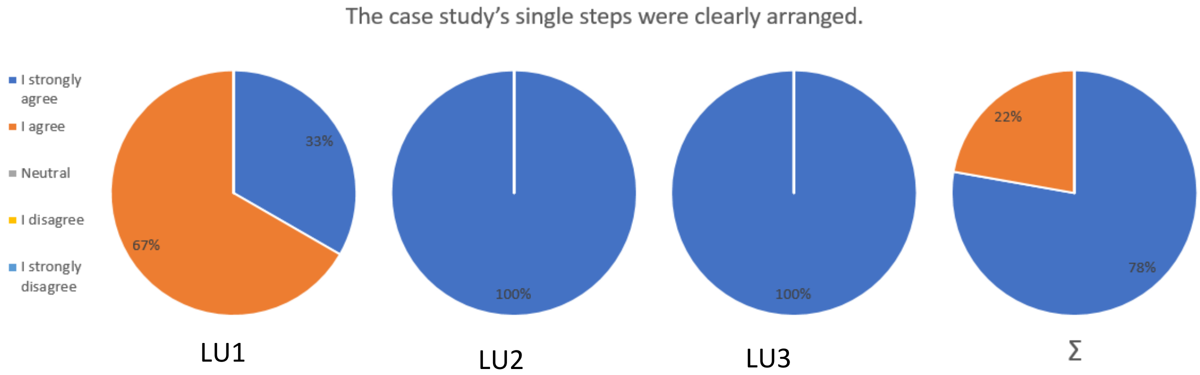

Figure 62: Evaluation of the Survey Questions Q1.31, Q2.32 and Q3.30 (Source: Own Representation)

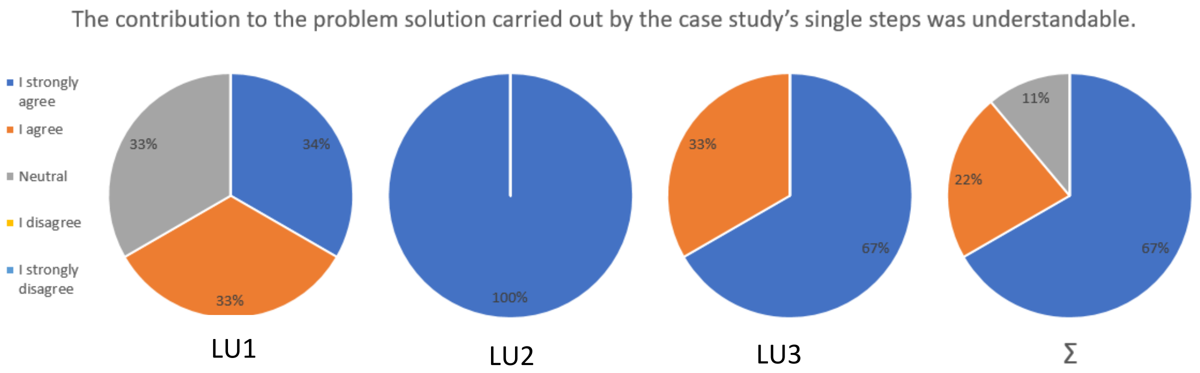

Figure 63: Evaluation of the Survey Questions Q1.32, Q2.33 and Q3.31 (Source: Own Representation)

According to Figure 64, again at least 67% per learning unit agreed or strongly agreed on understandable and easy performable instructions and figures. The 33% neutral attitude towards this evaluation question might be explained with the complexity of building the experimental setup and configuring the Raspberry Pi using the prompt.

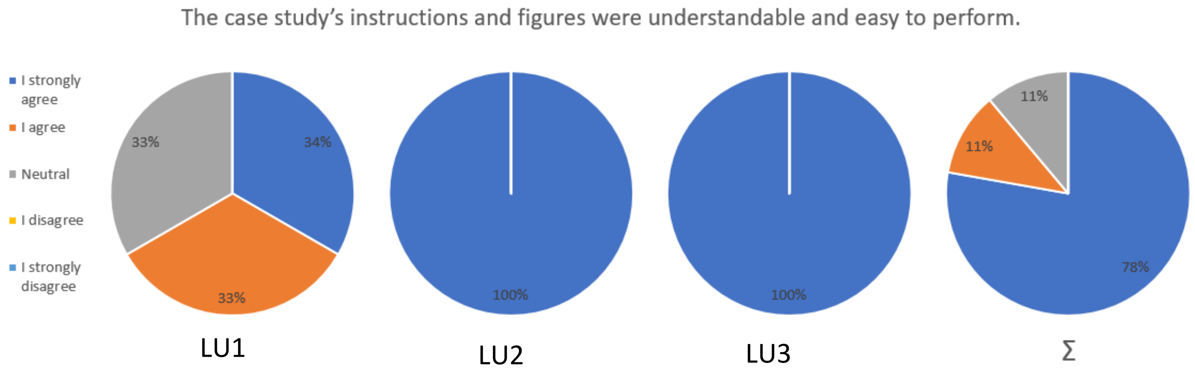

Figure 64: Evaluation of the Survey Questions Q1.33, Q2.34 and Q3.32 (Source: Own Representation)

One can note that during the case study evaluation no answer was rated worse than neutral. At the same time, among all curriculum unit participants, only three neutral votes were made. This constitutes a satisfactory evaluation feedback regarding the practical curriculum module parts.

Total curriculum unit:

As plotted in Figure 65, in average 78% of the participants were strongly convinced that its level of difficulty was appropriate. The 33% neutral votes recorded for LU 2.4.2 and LU 2.4.4 can be explained with the fact that the respective curriculum units' participants did not have prior knowledge in the fields of Sensor Technology and SAP Predictive Analytics. In contrast to that, the students which evaluated LU 2.4.3 did already have prior experience in Data Modelling and working with SAP HANA / SAP HANA Studio.

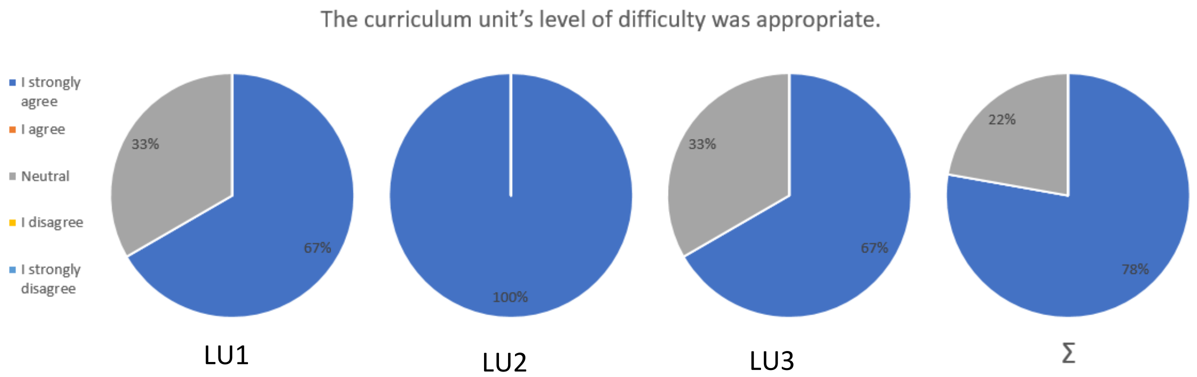

Figure 65: Evaluation of the Survey Questions Q1.35, Q2.36 and Q3.34 (Source: Own Representation)

Finally, Q1.36, Q2.37 and Q3.35 requested a rating of the entire learning unit carried out by the students on a scale from 1 to 6 according to the German school grading system. While LU 2.4.2 and LU 2.4.3 were graded with 2.66, learning unit LU 2.4.4 achieved the best possible score with 1,0.

There must be noticed that LU 2.4.2 was once rated with a 5 and LU 2.4.3 with a 6 has a high impact on the total average grade considering the number of three evaluation participants per learning unit. Based on the previous findings, these grades are unrealistic. One can assume that the evaluating persons confused the previous used Likert scale, having 5 as highest possible score and the German school grading scale, having 1 as highest possible score.

5.6.3.4 EQ4: Do Students Have Specific Improvement Suggestions?

Survey questions Q1.25, Q1.34, Q1.37, Q2.26, Q2.35, Q2.38, Q3.24, Q3.33, and Q3.36 were designed as text fields for provision of specific improvement suggestions in text form. The students were asked regarding the respective theory slides, the case studies, and the curriculum unit as a whole. In total, four suggestions of this kind were made. As they were all submitted in German, they were translated to English for the context of this thesis. In the following, the different suggestions are presented and discussed:

"The case study takes an already collected data set as starting point. As the topic is 'Integrating Sensors', the focus should maybe lie more on the actual sensor data and on how they are collected." This suggestion was given for the case study in the second learning unit. However LU 2.4.3 deals with the utilization of already collected sensor data for data analysis and reporting in order to support decision making processes. The raised points are addressed in detail by LU 2.4.2.

Regarding a general statement and suggestion to the curriculum, one participant wrote: *"It's difficult to evaluate the curriculum as a whole after carrying out only one case study"* This statement verifies the modular nature of the curriculum. Nevertheless, this survey question meant to evaluate the carried-out learning unit, not the curriculum itself. The evaluation of the curriculum itself was conducted with lecturers as described in previous paragraphs of this thesis.

With regards to the case studies, the students commented: *"Seems to be too small. After application of the Apriori algorithm, another algorithm could be implemented (e.g. a decision tree) to visualize the classification. Maybe it would also make sense to introduce the usage of R in combination with HANA to the students."* *"Interpret model outcome and show next steps for the concrete usage in a bike sharing application."* However, as the next paragraph will show, the evaluating students indeed worked for a shorter time on the case study as expected. Each of the three evaluating students had prior knowledge in the field of Data Mining / Machine Learning. It can be expected that especially students with a low level of prior knowledge in that area experience difficulties in understanding the association analysis with the Apriori algorithm, as it is not a trivial topic.

Moreover, the model outcome is visualized in two different ways. The implementation of a decision tree for the concrete usage in a bike sharing application would make sense in this case and can be seen as the next step to be taken, which can be considered as a topic for further development in the curriculum.

Just like the above-mentioned point, the usage of R in combination with SAP HANA could be another topic to be imparted to students.

5.6.3.5 EQ5: Are the Estimated Time Specifications for each Learning Unit Correct?

This chapter answers EQ5, which aims to verify the learning unit's time specification. Table 20, Table 21 and Table 22 in Attachment F: Time Specifications for Learning Units oppose the estimated time and the actual time required during the evaluation sessions.

The time specification measurements of LU 2.4.2 and LU 2.4.3 reveal only marginal deviations from the estimated time specifications. As deviations in that scale can originate from different skill levels of students, no adjustments were carried out.

Regarding LU 2.4.4, the time specification measurements show strong deviations in the estimation of the required time for the third case study part. Consequently, the decision was taken to reduce the time specification for that part from 50 min. to 30 min.

Furthermore, an interesting thing to notice is that for every learning unit the time required for the case study completion was shorter for the participants working in a group. This again verifies the benefit of the decision to carry out the curriculum module's practical parts in teams.

The results of this evaluation were overall positive, and it was proved that the delivered content helped the students in improving their competencies or developing new ones. Due to the small number of participating students, the curriculum could be evaluated by a higher number of participants in the future. However this results show that the concept of the curriculum helps in improving the aimed competencies and delivers the desired outcome.

5.7 Conclusion

In this chapter the developed curriculum for evaluation steps were proposed and carried out from four different perspectives. First of all based on research literature and a thorough analysis an evaluation model that can be applied from lecturers for evaluating their courses was developed. The model includes various aspects to be evaluated and suggests evaluation questions from the literature for each of the aspects. Lecturers can take the model into consideration and use the specific tools for evaluating the desired aspects in their courses. This can also be considered as a last accompaniment tool of the curriculum that helps lecturers in assessing their courses.

For evaluating the curriculum itself a three steps approach was followed. During the development a curriculum pilot was released and evaluated by conducting surveys with a selected group of lecturers. This was the first step of the evaluation. The pilot includes lecturers that could take part of a five day workshop, where parts of the curriculum were introduced and discussed as well as lecturers that received the whole curriculum online and could analyze it on themselves. Both groups were sent a link with the evaluation survey where they could express their opinions and suggestions. This evaluation delivered a good overall valuation and gave some helpful suggestions that were considered before the final curriculum release.

In the second step the complete developed curriculum was evaluated. For this purpose two podium discussions with selected professors of the field were conducted. During these discussion feedback and input was collected. Further on the participants from the public in the podium were given surveys to also give their evaluation about the curriculum. While the overall valuation of the curriculum was very positive, some suggestions were made that were either directly implemented: e.g. I wish to download the complete materials as zip, which was made technically possible, as well as further suggestions e.g. offering a module in the area of HCM which will be considered in later releases of the curriculum.

As a third and last step of the curriculum evaluation one complete module was evaluated in class with students in form of a workshop. This was conducted as an example to prove that the applied approach and method throughout the modules, delivers the desired results in teaching. For this purpose the self-assessment approach was applied. For each of the defined learning outcomes of the unit to be evaluated, self-assessment questions were developed. The participating students had to respond these questions before participating in the workshop and afterwards. In this way it could be measured if the learning outcomes are fulfilled. This delivered an overall good valuation and proved that the applied approach in the curriculum fulfills the predefined learning outcomes.

The evaluation results confirm that the concept of the curriculum and the applied method delivers the desired results. It proves that the curriculum reaches its goal and provides a collection of content and methods to be applied for teaching the competencies needed for Industry 4.0. Some valuable feedback and possibilities for improvement were collected during the curriculum, which were considered and applied in the final product.

6 Summary

6.1 Conclusion & Discussion

The goal of this thesis was to address one of the challenges of Industry 4.0 that is the qualification of future employees with the necessary competencies to act and work in the transformed work environment. The thesis can be categorized in the research area of IS Education. The work is organized into three research questions that structure the work as well as the research approach. For this purpose, in this thesis a competency model was developed and evaluated in the first research question by focusing on professions in the areas of IS, CS and Engineering. Based on these competencies, a competency-based curriculum was developed by following a structured didactical approach in the second research question. In the third and last research question a multidimensional evaluation of the curriculum was conducted to validate the generated results. In the following part of this section, the results of this thesis will be summarized.

In the introductory **Chapter 1** the research gap and motivation for this thesis is presented by arguing the relevance of the topic and this research. The thesis is limited on the target groups of IS, CS and Engineering professionals which is argued and presented at the beginning in order for the reader to be able to focus the results of the thesis on this group. The work is structured in three research questions where each gives answers to a part of the research gap and builds on one another for completing the results of the work. These research questions as well as the applied research methods are presented and described at the beginning of the thesis followed by an overview of the thesis structure.

This work arose and was written at the SAP UCC Munich, an education institute that provides SAP Systems and Curricula for teaching and research purposes. In this context a curriculum development project was defined. This thesis was written in the context of this project and some results of the thesis are also part of the curriculum development project. The project and research context in which this thesis was written is described at the beginning.

The following **Chapter 2** focuses on defining the main concepts applied throughout the thesis by providing the scientific background for the work. This includes the concept of Industry 4.0, Curriculum, Competency and Competency Model. All these terms are discussed based on the literature status quo, where various definitions and research aspects for each of the concepts is taken into consideration. In order for the reader to have a clear understanding of how each of these concepts is used in this thesis, a definition of each of them in the context of this thesis is provided.

Chapter 3 provides a competency model for Industry 4.0 that covers three areas: IS, CS and Engineering, which is the target group of this thesis and addresses the first research question of this thesis:

What competencies are critical for job positions that require higher education for effectively and efficiently performing in Industry 4.0?

To answer this question a literature review is conducted in order to extract competencies for Industry 4.0. Since the topic is new, only little research exists. Therefore to complete the results additional practitioner's literature was taken into consideration. After analyzing the literature, a total of 64 competencies for Industry 4.0 could be extracted. In order to evaluate these results as well as further expand them with empirical data, focus group discussions were conducted by following the Critical Incident Technique approach. A total of four focus groups were conducted with experts from the educational area such as lecturers and professors from the EMEA region. As a result, a total of 69 evaluated competencies were extracted. These competencies were used for building a competency model for Industry 4.0. For this purpose, the SHL Competency Framework was used. This framework provides a state of the art standard widely used in research and practice. This way the generated results have practical as well as scientific implications. By using the framework and the defined 69 competencies a competency model for Industry 4.0 could be developed that covers three professional areas, relevant for Industry 4.0: IS, CS and Engineering.

The results delivered mostly competencies of behavioral nature that are relevant for all three areas. Only few competencies are related to domain knowledge and can be partly assigned to a certain area as IS, CS and Engineering. This demonstrates a shift in the work of the future, where it will become more interdisciplinary and it is more relevant for professionals to provide behavioral competencies, while the domain related ones will be partly substituted by automatic processes. The competencies defined in this chapter are not new, however their combination in the context of Industry 4.0 shows a clear tendency of how the work life will change. In order for the reader to gain a better understanding of the single competencies as well as their relevance in Industry 4.0, a detailed explanation for each competency is provided.

In **Chapter 4**, a competency-based curriculum is developed by following a didactical six steps approach for curriculum development and addressing the second research question:

Which didactic concepts, contents and hands-on experiences are required for a competency-based Industry 4.0 curriculum?

The curriculum offers a collection of materials including theory and practical materials that can be used from lecturers to address relevant topics of Industry 4.0. Based on the defined competencies 19 topics of interest that should be included in the curriculum as single modules were defined and organized in nine sections based on the thematic. For each of the modules learning outcomes based on the taxonomical criteria were defined that helped in conceptualizing them and defining the content afterwards. The author of this thesis was responsible for the development of six of the 19 modules that are also part of this thesis. Each module includes various learning units that address various aspects of the topic and include slides to teach the theoretical part as well as exercises and case studies. Principles of experiential learning and cognitive learning process are applied throughout the curriculum in order to provide interactive state-of-the-art learning materials. The interaction is also an important factor in teaching and training behavioral competencies such as teamwork or communication. In order to help the lecturers in organizing their lectures better, additional measures are provided. This includes pre-designed learning journeys with preselected materials that can be applied in teaching as e.g. a full course, a collection of relevant and free available MOOCs for each topic, a course calculator that can be considered while designing a course, as lecturer notes explaining how the materials can be used as well as describing necessary steps for preparing for the lesson, etc. The whole curriculum in built on a teaching case approach based on a model company that is used in every module throughout the whole curriculum. This approach helps in better understanding the topic based on a concrete example and keep the student's interest alive.

Chapter 5 addresses the evaluation of the curriculum and answers the third research question:

What are the effects and results of the curriculum application on the target group?

Based on a literature analysis an existing curriculum evaluation model was expanded and adapted for the needs of IS curricula. For each aspect of the model, evaluation questions from the literature are suggested. This offers a tool for lecturers to evaluate aspects of the curriculum while using it in a course.

Furthermore, the curriculum as an artefact was evaluated in three steps. In a first step a pilot evaluation was conducted in order to gain feedback and offer the possibility to improve aspects of the curriculum. For the pilot, expert lecturers and professors interested in participating in the evaluation were selected. Some of the experts were able to participate in a five-day workshop where the curriculum was presented, while the others received the complete curriculum content online. Afterwards both groups were asked to evaluate the curriculum by using an online survey including open and closed questions. The results of the evaluation were very good and some valuable feedback could be gathered for further improving the curriculum.

After the curriculum was released, a complete evaluation of the curriculum structure, presentation, concept and materials as a whole was conducted. For this purpose, two podium discussions were conducted with four professors in each discussing about the curriculum. These discussions were recorded and analyzed. In addition to the discussions in the podium, the participating public could also present their opinions by filling a short survey with open and closed questions. Both the qualitative and quantitative data was analyzed and while some of the suggestions were directly implemented, the rest is documented for future releases of the curriculum. The overall evaluation was very good.

As a last step of the curriculum, one module was evaluated in order to gain feedback from the students and validate how the predefined learning objectives are fulfilled. A total of three sessions were conducted with students in form of a workshop, where one different learning unit from the module was conducted in each. For this purpose, self-assessment questions were defined for each learning objective that includes a competency. The participating students had to respond the question before and after participating to the workshop. In total the competency level was increased after conducting the learning unit, which validates the applied approach.

At the end of this thesis, the current **Chapter 6** summarizes the results and presents some limitations of this work as potential topics for further research.

6.2 Limitation & Further Research

Similar to every research, this thesis also presents some limitations that are going to be analyzed in this section. This work had a clearly defined target group by focusing on IS, CS and Engineering professionals. However, in Industry 4.0 almost every area of work and every profession will be influenced by the digital transformation. Therefore, analyzing competencies and teaching concepts for further disciplines might be a point that could be addressed in future research.

For the evaluation of the competency model in the first research question or the evaluation of the curriculum in the third research question, empirical data was collected from experts e.g. through focus groups, survey or podium discussions. These experts included mainly lecturers and professors from the EMEA region. While they represent a group that is good informed about the topic and brought valuable input, it would be good to also gather information and feedback from people from the industry as well as from other regions apart from EMEA. Every branch and every culture often underlines different aspects. Consequently, a holistic view might be presented by taking into consideration other target groups. This offers potential for further research.

The presented curriculum is of a general nature and offers an introduction to various relevant topics for the digital transformation towards Industry 4.0. It helps in understanding the relevance of Industry 4.0 and how it affects various aspects of the company by offering a module for each of the topics such as strategy, innovation as well as topics related to the technology like sensors or big data. However, the curriculum does not provide a detailed deep dive into the topics since this was not in its scope or its defined learning outcomes. On the other hand it would be helpful if competency-based curricula that offer deep dive learning into the different topics are offered. This work gives a first input and presents an approach that was shown to be successful in developing such curricula for modern topics of the Industry 4.0.

A further point for research is in the didactic approach and method. For developing a competency-based curriculum, the six steps approach for curriculum development was adapted. However, although many curriculum development models are available in the literature, there is a lack of concrete approaches for competency-based curriculum development. The method applied in this thesis as well as further ones suggest e.g. defining learning outcomes based on a taxonomy and afterwards defining the content that aims in achieving these learning outcomes. Although there are some suggestions and taxonomical approaches, there is no clear method defined in the literature on how conduct this step. This lies in the hands of the experienced pedagogical staff. However, it would be helpful to have a clearly defined scientific method and approach on how to develop the content for this step.

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Attachment A: List of Publications

Prifti, L., Knigge, M., Kienegger, H., & Krcmar, H. (2017). *A Competency Model for "Industrie 4.0" Employees*. Paper presented at the International Conference on Wirtschaftsinformatik, St. Gallen.

Prifti, L., Knigge, M., Kienegger, H., & Krcmar, H. (2017). Un Modello die Competenze per i Lavoratori di Industria 4.0. *Professionalita Studi*, 1(1).

Prifti, L., Levkovskyi, B., Knigge, M., & Krcmar, H. (2018). *Developing an Evaluation Model for Information Systems Curricula*. Paper presented at the MKWI, Leuphana.

Prifti, L. (2017). *Professional Qualification in "Industrie 4.0": Building a Competency Model and Competency Based Curriculum.* Presented at the Doctoral Consortium - International Conference on Wirtschaftsinformatik, St. Gallen.

Prifti, L., Heininger, R., Utesch, M., Krcmar, H., (2017). *Analysis and Evaluation of Tools, Programs, and Methods at German University to Support the Study Skills of School Students*. Paper presented at EDUCON 2017, Athen.

Prifti, L., Knigge, M., Löffler, A., Hecht, S., Krcmar, H., (2017). Emerging Business Models in Education Provisioning: A Case Study on Providing Learning Support as Education-as-a-Service. *International Journal of Engineering Education*, 2017 (3).

Prifti, L., Heininger, R., Hecht, S:, Krcmar, H., (2014). *Service Desk Requirements for a Cloud Service Provider*. MKWI. Paderborn.

Bögelsack, A., Baader, G., **Prifti, L**., Zimmermann, R., Krcmar, H., (2015) *SAP-Systeme in der Cloud: Implementierung und Betrieb*. Rheinwerk Verlag. Germany.

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Heininger, R., **Prifti, L**., Seifert, V., Utesch, M., Krcmar, H., (2017). *Teaching How to Program With a Playful Approach: a Review of Success Factors*. Paper presented at EDUCON 2017, Athen.

Heininger, R., Seifert, V., **Prifti, L**., Utesch, M., Krcmar, H., (2017). *A playful approach to learning how to program: a structured lessons plan*. Bled eConference. Slovenia.

Heininger, R., **Prifti, L**., Böhm, M., Krcmar, H., (2016). *Towards a Model of Heterogeneity in IT Service Value Networks*: Results from a Literature Review. Bled eConference. Slovenia.

Knigge, M., **Prifti, L**., Kienegger, H., Krcmar, H., (2017). *Teaching Enterprise Organization and Enterprise Resource Planning Systems in Schools: Playing a Serious Game with Pupils*. Paper presented at EDUCON 2017, Athen.

Knigge, M., **Prifti, L**., Hecht, S., Krcmar, H., (2017). *Text Mining on Job Offers Using SAP HANA: Analyzing Skill and Competency Requirements for Industry 4.0.* Report. HPI Potsdam.

Knigge, M., **Prifti, L**., Hecht, S., Krcmar, H., (2017). *Follow-Up Project: Automated Text Mining on Job Offers Using SAP HANA: Analyzing Skill and Competency Requirements for Industry 4.0*. Report. HPI Potsdam.

Löffler, A., **Prifti, L**., Knigge, M., Kienegger, H., & Krcmar, H. (2017). *Teaching Business Process Change in the Context of the Digital Transformation: A Review on Requirements for a Simulation Game*. Paper presented at the MKWI, Leuphana.

Utesch, M., Seifert, V., **Prifti, L**., Heininger, R., Krcmar, H., (2017). *The Playful Approach to Teaching How to Program: Evidence by a Case Study*. International Conference on Interactive Collaborative Learning. Budapest.

Attachment B: Survey for the Pilot Evaluation

Section 1 – Structure of the curriculum: The curriculum is built on a teaching case approach, by using an existing bike company and further expanding it. It is modularly built by including many modules that are also combined in learning journeys. The whole content is structured in an HTML application. In this part the lecturers have to evaluate these aspects with regard to the structure and can give their opinions in the additional fields. The provided questions are:

- *Transformation from Global Bike to "GBS"*
  - How do you rate the idea of sticking to the GBI-story and keeping the context for this new curriculum? (Likert Scala)
  - How do you rate the new story/teaching cases of GBS in general? (Likert Scala)
  - I like... (Free text)
  - I wish... (Free text)
- *Modules*
  - How do you rate the idea of providing a modularly built curriculum where you can select your topics from different modules? (Likert Scala)
  - If you have a look at the modules, do you miss topics? If so, which? (Free text)
  - How do you rate the idea of providing links to related SAP University Alliances content? (Likert Scala)
  - How do you rate the idea of providing links to third-party content, e.g., massive open online courses (MOOCs) such as provided from open.sap.com? (Likert Scala)
  - Do you miss additional links to third-party contents in any topic? If so which? (Free text)
  - I like... (Free text)
  - I wish... (Free text)
- *Learning Journeys*
  - How do you rate the idea of providing learning journeys for specific topics? (Likert Scala)
  - Which topics would you like to see provided as learning journeys? (Free text)
  - I like... (Free text)
  - I wish... (Free text)
- *HTML Application*
  - How do you rate the idea of using an HTML application for navigating through the curriculum? (Likert Scala)
  - How do you rate this specific implementation? (Likert Scala)
  - What can be improved with this HTML application? (Free text)
  - I like... (Free text)
  - I wish... (Free text)

Section 2 – Provided Materials: The curriculum has a large number of materials including slide decks, case studies, exercises, hands-on etc. Abbreviations and Glossary are provided as additional tools. In this section the lecturers can evaluate these aspects pf the curriculum since this is one of the core deliverables that this curriculum provides. The provided questions are:

- *Theory: Slide decks*
    - How do you rate the slide decks in general? (Likert Scala)
    - Do you have comments to specific slide decks? (Free text)
    - How do you rate the overview of competencies that are taught with each slide deck ("At the end of this unit…")?(Likert Scala)
    - How do you rate the discussion slides, available in some of the slide decks? (Likert Scala)
    - I like... (Free text)
    - I wish... (Free text)
- *Hands-on: Exercises and Case Studies*
    - How do you rate the exercises and case studies in general? (Likert Scala)
    - How do you rate the interrelation between slides and case studies? (Likert Scala)
    - How do you rate the teaching cases as part of the case studies? (Likert Scala)
    - How do you rate the team/discussion/interaction case studies? (Likert Scala)
    - Do you have comments to specific exercises or case studies? (Free text)
    - I like... (Free text)
    - I wish... (Free text)
- *List of Abbreviations and Glossary*
    - Do you think it is helpful to have such a list of abbreviations? (Free text)
    - Do you think it may be helpful to have a glossary with short overviews over specific topics? (Free text)
    - I like... (Free text)
    - I wish... (Free text)

Section 3 – Provided System: Some of the delivered hands-on exercises are based on an S/4 HANA system. Therefore here the evaluation aims this special aspect of the curriculum – the applied technology. This part was however optional since not all the participants used the S/4 HANA system. So the ones who used it could fill the evaluation. The provided questions are:

- How do you rate the usability of the system? (Likert Scala)
- How do you rate the performance of the system? (Likert Scala)
- How do you rate the selection of Fiori apps for the case studies? (Likert Scala)
- Did you face problems with the systems? If so, what kind of problems? (Free text)
- I like... (Free text)
- I wish... (Free text)

Section 4 – General: In this section free text fields are provided in case the participants have further feedback, input or ideas. In this case they have the possibility once again to express their opinion if it was not covered by the questions above. The provided questions are:

- Do you want to tell us something else? (Free text)

Section 5 – Statistical Information: In this section some questions for statistical purposes are provided as: country, experience, courses and degree. The provided questions are:

- In which country do you mostly teach? (Dropdown list)
- What is your teaching experience? (Dropdown list)
- At what kind(s) of institution(s) do you teach? (multiple selection possible) (Check boxes)
- What kind(s) of student(s) do you teach? (multiple selection possible) (Dropdown list)
- What kind(s) of subject(s) do you teach?(multiple selection possible) (Check boxes)
- If you want, you can leave us your email address, so that we can contact you in the future. (Free text)

Attachment C: Evaluation of Learning Units - Agenda

Table 14: Agenda Session LU 2.4.2

Activity	Questions	Teaching methodology	Medium	Time
Kick Off: Introduction and Overview	-	Presentation	PowerPoint	5 min
Evaluation: Determination of prior knowledge level and personal information	Q1.1-Q1.21	-	Survey	5 min
Theoretical Part	-	Presentation	PowerPoint	40 min
Practical Part	-	Interactive case study	Task Sheet, Raspberry Pi, SAP HANA Studio	140 min
Evaluation: Determination of final knowledge level and case study design	Q1.4-Q1.37	-	Survey	15 min
Total	-	-	-	**205 min**

Table 15: Agenda Session LU 2.4.3

Activity	Questions	Teaching methodology	Medium	Time
Kick Off: Introduction and Overview	-	Presentation	PowerPoint	5 min
Evaluation: Determination of prior knowledge and personal information	Q2.1-Q2.22	-	Survey	5 min
Theoretical Part	-	Presentation	PowerPoint	40 min
Practical Part	-	Interactive case study	Task Sheet, SAP HANA Studio, SAP Lumira	105min
Evaluation: Determination of final knowledge level and case study design	Q2.4-Q2.38	-	Survey	15 min
Total	-			**170 min**

Table 16: Agenda Session LU 2.4.4

Activity	Questions	Teaching methodology	Medium	Time

Kick Off: Introduction and Overview	-	Presentation	PowerPoint	5 min
Evaluation: Determination of prior knowledge and personal information	Q3.1-Q3.20	-	Survey	5 min
Theoretical Part		Presentation	PowerPoint	40 min
Practical Part		Interactive case study	Task Sheet, SAP HANA Studio, SAP Predictive Analytics	90 min
Evaluation: Determination of final knowledge level and case study design	Q3.4-Q3.36	-	Survey	15 min
Total				**155 min**

Attachment D: Learning Outcomes of the Learning Units

Learning Unit 2.4.2: Data Collection with Sensors

After completing this module, you will be able to…

- LO1.A utilize innovative technologies like SAP HANA for building high-performance IoT solutions.
- LO1.B explain how a Raspberry Pi works and how to set it up initially.
- LO1.C compare the technical features and characteristics of different sensors and analyze their differences.
- LO1.D establish a connection to a sensor from a Raspberry Pi.
- LO1.E implement a script for automated sensor data collection.
- LO1.F import data to a SAP HANA in-memory database and visualize it in SAP HANA Studio from IT architecture and software perspectives.
- LO1.G integrate heterogeneous and interdisciplinary technologies into a holistic IoT solution.
- LO1.H evaluate IoT concepts and the purpose of IoT devices in innovative business models.
- LO1.I evaluate IoT solutions facing common challenges of companies in the digital transformation process.
- LO1.J apply knowledge, solve problems and develop solutions in a team.

Learning Unit 2.4.3: Data Analytics and Reporting with Sensor Data

After completing this module, you will be able to…

- LO2.A utilize innovative technologies like SAP HANA for building high-performance IoT solutions.
- LO2.B understand and explain a complex data model consisting of a big data set retrieved by sensors.
- LO2.C apply technical and conceptual knowledge in order to model big data sets to increase the information value.
- LO2.D model big data in order to be suitable for decision-making.
- LO2.E use SAP HANA Studio and SAP Lumira.
- LO2.F model big data sets in a SAP HANA environment.
- LO2.G analyze a prepared data set from a statistical perspective.
- LO2.H interpret analysis results emerging out of big data and put them in a business context.
- LO2.I visualize analysis results emerging out of big data for business reports.
- LO2.J present analysis results emerging out of big data in order to support a decision-making process.
- LO2.K identify and critically analyze strengths and weaknesses of a business and appropriately redesign business strategy.
- LO2.L integrate heterogeneous and interdisciplinary expertise into a holistic IoT solution.

LO2.M apply knowledge, solve problems and develop solutions in a team.

Learning Unit 2.4.4: Data Mining & Machine Learning with Sensor Data:

After completing this module, you will be able to…

LO3.A utilize innovative technologies like SAP HANA for building high-performance IoT solutions.
LO3.B understand and explain a complex data model consisting of a big data set retrieved by sensors.
LO3.C use SAP Predictive Analytics and SAP Predictive Analytics Library algorithms.
LO3.D apply the full Data Analytics knowledge discovery process from the technical and conceptual perspective on an example data set with focus on:

i. performing common preprocessing algorithms in a SAP HANA environment.
ii. applying Data Mining and Machine Learning algorithms in order to train a model based on a big data set in a SAP HANA environment.

LO3.E analyze the suitability of Data Mining/Machine Learning models depending on the business context.
LO3.F interpret the model outcome in a business context and visualize the results.
LO3.G rate the value proposition of Data Mining/Machine Learning in combination with IoT in business models.
LO3.H discover and implement new revenue streams in business models.
LO3.I develop customer oriented service offerings based on IoT and Big Data Analytics.
LO3.J integrate heterogeneous and interdisciplinary expertise and technologies into a holistic IoT solution.
LO3.K apply knowledge, solve problems and develop solutions in a team.

Attachment E: Survey Questions for the Learning Unit Evaluation

The learning outcomes used in the tables are listed in Attachment D: Learning Outcomes of the Learning Units.

Table 17: Survey Questions Session LU 2.4.2 - Data Collection with Sensors

Topic	Question		Learning Outcome(s)	Evaluation Question
General Information / Prior Knowledge	Q1.1	Study program		EQ1
	Q1.2	Study level		EQ1
	Q1.3	I have prior knowledge in the following area(s): Sensor Technology Raspberry Pi SAP HANA / SAP HANA Studio SAP Lumira SAP Predictive Analytics Data Mining / Machine Learning		EQ1
Raspberry Pi	Q1.4	I know, what a Raspberry Pi is and what it can be used for.	LO1.B	EQ2
	Q1.5	I know how to set up a Raspberry Pi initially.	LO1.B	EQ2
Sensor Technology	Q1.6	I know, what a sensor is and what it can be used for.	LO1.A, LO1.C	EQ2
	Q1.7	I can compare the technical features and characteristics of at least two specific sensors and explain their differences.	LO1.A, LO1.C	EQ2
Automated Sensor Data Collection	Q1.8	I can name the electronic and hardware components necessary for connecting a sensor to a Raspberry Pi.	LO1.D	EQ2
	Q1.9	I know how to build an experimental setup to connect a sensor to a Raspberry Pi using these electronic and hardware components.	LO1.D	EQ2
	Q1.10	I know how to access a sensor from a Raspberry Pi.	LO1.D	EQ2
	Q1.11	I have basic knowledge in Python.	LO1.E	EQ2
	Q1.12	I know how to automate sensor data collection.	LO1.E	EQ2
IoT with SAP HANA	Q1.13	I can explain the advantages of using innovative technologies like SAP HANA for IoT solutions.	LO1.A, LO1.F	EQ2
	Q1.14	I know how to utilize SAP HANA in order to build a high-performance IoT solution.	LO1.A, LO1.F	EQ2
	Q1.15	I can name different technologies integrated in a holistic IoT solution.	LO1.G	EQ2
	Q1.16	I can explain the purpose of IoT devices in innovative business models.	LO1.H	EQ2

	Q1.17	I can evaluate IoT solutions facing common challenges of companies in the digital transformation process.	LO1.I	EQ2
	Q1.18	I know the concept of IoT and how sensors are related to it.	LO1.I	EQ2
Group Work	Q1.19	I experienced the problem solving in groups with a partner as more productive and helpful. (participants working in a group) / I experienced the problem solving by myself as more productive and helpful. (participants working by themselves)	LO1.J	EQ2
	Q1.20	In future, I would prefer working by myself compared to working in a group. (participants working in a group) / In future, I would prefer working in a group than working by myself. (participants working by themselves)	LO1.J	EQ2
	Q1.21	Both group members contributed equally to the problem solution. (only for participants working in a group)	LO1.J	EQ2
Theory Slides	Q1.22	The theory slides contributed to the overall understanding of the topic.		EQ3
	Q1.23	The theory slide’s structure was clear.		EQ3
	Q1.24	The theory slides contributed to a successful completion of the case study.		EQ3
	Q1.25	Text field for improvement suggestions regarding the theory slides.		EQ4
Case Study	Q1.26	The presented case study’s complexity was appropriate.		EQ3
	Q1.27	The presented case study was realistic.		EQ3
	Q1.28	The presented case study was interesting.		EQ3
	Q1.29	The presented case study was suitable for mediating content related to the topic IoT: Integrating Sensors into Big Data Analytics		EQ3
	Q1.30	The case study’s overall structure was clear.		EQ3
	Q1.31	The case study’s single steps were clearly arranged.		EQ3
	Q1.32	The contribution to the problem solution carried out by the case study’s single steps was understandable.		EQ3
	Q1.33	The case study’s instructions were understandable and easy to perform.		EQ3
	Q1.34	Text field for improvement suggestions regarding the case study.		EQ4

Summary	Q1.35	The curriculum unit's level of difficulty was appropriate.		EQ3
	Q1.36	Please rate the curriculum on a scale from 1 to 6 starting by 1.		EQ3
	Q1.37	Text field for improvement suggestions regarding the curriculum unit.		EQ4

Table 18: Survey Questions LU 2.4.3 - Data Analytics and Reporting with Sensor Data

Topic	Question		Learning Outcome(s)	Evaluation Question
General Information / Prior Knowledge	Q2.1	Study program		EQ1
	Q2.2	Study level		EQ1
	Q2.3	I have prior knowledge in the following area(s): Sensor Technology Raspberry Pi SAP HANA / SAP HANA Studio SAP Lumira SAP Predictive Analytics Data Mining / Machine Learning		EQ1
Understanding Big Data sets	Q2.4	I can identify interrelations in big data sets by interpreting an UML diagram.	LO2.B	EQ2
	Q2.5	I understand how big data sets can be retrieved by sensors.	LO2.A, LO2.B	EQ2
Data Modelling	Q2.6	I can apply basic concepts of data modelling.	LO2.C	EQ2
	Q2.7	I understand, how data modelling can increase the information value of data.	LO2.C, LO2.D	EQ2
SAP HANA / Lumira	Q2.8	I know the basic capabilities of SAP HANA Studio and can make use of them.	LO2.E	EQ2
	Q2.9	I know the basic capabilities of SAP Lumira and can make use of them.	LO2.E	EQ2
	Q2.10	I can explain the advantages of using innovative technologies like SAP HANA for Big Data solutions.	LO2.A, LO2.F	EQ2
	Q2.11	I know how to utilize SAP HANA for modelling big data sets.	LO2.A, LO2.F	EQ2
	Q2.12	I know how to utilize SAP Lumira for data visualization.		EQ2
Data Analysis and Reporting in the Business Context	Q2.13	I can analyze a prepared data set from a statistical perspective.	LO2.G	EQ2
	Q2.14	I can interpret analysis results emerging out of big data and put them in a business context.	LO2.H	EQ2
	Q2.15	I can visualize analysis results emerging out of big data for business reports.	LO2.I	EQ2

	Q2.16	I can present analysis results emerging out of big data in order to support a decision-making process.	LO2.J	EQ2
	Q2.17	I understand how data analytics can be utilized to identify strengths and weaknesses of a business.	LO2.K	EQ2
	Q2.18	I can critically analyze strengths and weaknesses of a business and suggest appropriate measures regarding the adjustment of the business strategy.	LO2.K	EQ2
	Q2.19	I can name different technologies integrated in a holistic IoT solution utilizing big data analytics insights.	LO2.L	EQ2
Group Work	Q2.20	I experienced the problem solving in groups with a partner / by myself as more productive and helpful.	LO2.M	EQ2
	Q2.21	In future, I would prefer working by myself compared to working in a group. / In future, I would prefer working in a group than working by myself.	LO2.M	EQ2
	Q2.22	Both group members contributed equally to the problem solution. (only for group members)	LO2.M	EQ2
Theory Slides	Q2.23	The theory slides were understandable.		EQ3
	Q2.24	The theory slides were well structured.		EQ3
	Q2.25	The presentation of the theory slides contributed to a successful completion of the case study.		EQ3
	Q2.26	Text field for improvement suggestions regarding the theory slides.		EQ4
Case Study	Q2.27	The presented case study's complexity was appropriate.		EQ3
	Q2.28	The presented case study was realistic.		EQ3
	Q2.29	The presented case study was interesting.		EQ3
	Q2.30	The presented case study was suitable for mediating content related to the topic IoT: Integrating Sensors into Big Data Analytics		EQ3
	Q2.31	The case study was well structured.		EQ3
	Q2.32	The case study's single steps were clearly arranged.		EQ3
	Q2.33	The contribution to the problem solution carried out by the case study's single steps was understandable.		EQ3

	Q2.34	The case study's instructions were understandable and easy to perform.		EQ3
	Q2.35	Text field for improvement suggestions regarding the case study.		EQ4
Summary	Q2.36	The curriculum unit's level of difficulty was appropriate.		EQ3
	Q2.37	Please rate the curriculum on a scale from 1 to 6 starting by 1.		EQ3
	Q2.38	Text field for improvement suggestions regarding the curriculum unit.		EQ4

Table 19: Survey Questions LU 2.4.4 - Data Mining with Sensors

Topic	Question		Learning Outcome(s)	Evaluation Question
General Information / Prior Knowledge	Q3.1	Study program		EQ1
	Q3.2	Study level		EQ1
	Q3.3	I have prior knowledge in the following area(s): Sensor technology Raspberry Pi SAP HANA / SAP HANA Studio SAP Lumira SAP Predictive Analytics Data Mining / Machine Learning		EQ1
Understanding Big Data Sets	Q3.4	I can identify interrelations in big data sets by interpreting an UML diagram.	LO3.B	EQ2
	Q3.5	I understand how big data sets can be retrieved by sensors.	LO3.B	EQ2
Knowledge Discovery Process	Q3.6	I can explain the basic steps of the Knowledge Discovery Process.	LO3.D	EQ2
	Q3.7	I can delimit the terms "Statistics", "Data Mining" and "Machine learning".	LO3.D	EQ2
SAP Predictive Analytics / SAP PAL	Q3.8	I know the basic capabilities of SAP Predictive Analytics and can make use of them.	LO3.C, LO3.D	EQ2
	Q3.9	I know the basic algorithms provided by the SAP Predictive Analytics Library.	LO3.C, LO3.D	EQ2
	Q3.10	I can apply common preprocessing algorithms in a SAP HANA environment.	LO3.C, LO3.D	EQ2
	Q3.11	I can apply common Data Mining/Machine Learning algorithms in a SAP HANA environment.	LO3.C, LO3.D	EQ2

Data Analytics in the business context	Q3.12	I can determine the suitability of complex data mining models depending on the business context.	LO3.E	EQ2
	Q3.13	I can interpret the outcome of a data mining model, put it in a business context and visualize the results.	LO3.F	EQ2
	Q3.14	I can identify new revenue streams in business models evolving out of the value proposition of data mining and IoT.	LO3.G, LO3.H	EQ2
	Q3.15	I feel capable of improving the customer orientation of an IoT solution by using Data Analytics instruments.	LO2.A, LO3.I	EQ2
	Q3.16	I can name different technologies integrated in a holistic IoT solution utilizing big data analytics insights.	LO3.J	EQ2
	Q3.17	I can utilize innovative technologies like SAP HANA for building high-performance IoT solutions.	LO3.A	EQ2
Group Work	Q3.18	I experienced the problem solving in groups with a partner / by myself as more productive and helpful.	LO3.K	EQ2
	Q3.19	In future, I would prefer working by myself compared to working in a group. / In future, I would prefer working in a group than working by myself.	LO3.K	EQ2
	Q3.20	Both group members contributed equally to the problem solution. (only for group members)	LO3.K	EQ2
Theory Slides	Q3.21	The theory slides were understandable.		EQ3
	Q3.22	The theory slides were well structured.		EQ3
	Q3.23	The presentation of the theory slides contributed to a successful completion of the case study.		EQ3
	Q3.24	Text field for improvement suggestions regarding the theory slides.		EQ4
Case Study	Q3.25	The presented case study's complexity was appropriate.		EQ3
	Q3.26	The presented case study was realistic.		EQ3
	Q3.27	The presented case study was interesting.		EQ3
	Q3.28	The presented case study was suitable for mediating content related to the topic IoT: Integrating Sensors into Big Data Analytics		EQ3
	Q3.29	The case study was well structured.		EQ3

	Q3.30	The case study's single steps were clearly arranged.		EQ3
	Q3.31	The contribution to the problem solution carried out by the case study's single steps was understandable.		EQ3
	Q3.32	The case study's instructions were understandable and easy to perform.		EQ3
	Q3.33	Text field for improvement suggestions regarding the case study.		EQ4
Summary	Q3.34	The curriculum unit's level of difficulty was appropriate.		EQ3
	Q3.35	Please rate the curriculum on a scale from 1 to 6 starting by 1.		EQ3
	Q3.36	Text field for improvement suggestions regarding the curriculum unit.		EQ4

Attachment F: Time Specifications for Learning Units

Table 20: Time Specification Analysis LU 2.4.2

Activity	Estimated Time	Actual Time Group Work	Deviation Group Work	Actual Time Working by oneself	Deviation Working by oneself
Kick Off	5 min.	5 min.	0 min.	5 min.	0 min.
Pre-test	5 min.	5 min.	0 min.	5 min.	0 min.
Theory Slides	40 min.	43 min.	+3 min.	43 min.	+3 min.
CS Part 1	30 min.	33 min.	+3 min.	46 min.	+16 min.
CS Part 2	45 min.	43 min.	-2 min.	45 min.	0 min.
CS Part 3	15 min.	22 min.	+7 min.	22 min.	+7 min.
CS Part 4	30 min.	15 min.	-15 min.	12 min.	-18 min.
CS Part 5	20 min.	13 min.	-7 min.	5 min.	-15 min.
Total CS	**140 min.**	**126 min.**	**-14 min.**	**130 min.**	**-10 min.**
Post-test	15 min.	7 min.	-8 min.	10 min.	-5 min.
Total	**205 min.**	**186 min.**	**-19 min.**	**193 min.**	**-12 min.**

Table 21: Time Specification Analysis LU 2.4.3

Activity	Estimated Time	Actual Time Group Work	Deviation Group Work	Actual Time Working by oneself	Deviation Working by oneself
Kick Off	5 min.	5 min.	0 min.	5 min.	0 min.
Pre-test	5 min.	5 min.	0 min.	5 min.	0 min.
Theory Slides	40 min.	45 min.	+5 min.	45 min.	+5 min.
CS Part 1	20 min.	20 min.	0 min.	20 min.	0 min.
CS Part 2	40 min.	25 min.	-15 min.	40 min.	0 min.
CS Part 3	45 min.	17 min.	-28 min.	33 min.	-12 min.
Total CS	**105 min.**	**62 min.**	**-43 min.**	**93 min.**	**-12 min.**
Post-test	15 min.	10 min.	-5 min.	10 min.	-5 min.
Total	**170 min.**	**127 min.**	**-43 min.**	**158 min.**	**-12 min.**

Table 22: Time Specification Analysis LU 2.4.4

Activity	Estimated Time	Actual Time Group Work	Deviation Group Work	Actual Time Working by oneself	Deviation Working by oneself
Kick Off	5 min.	5 min.	0 min.	5 min.	0 min.
Pre-test	5 min.	5 min.	0 min.	5 min.	0 min.

Theory Slides	40 min.	43 min.	+3 min.	43 min.	+3 min.
CS Part 1	20 min.	16 min.	-4 min.	20 min.	0 min.
CS Part 2	20 min.	6 min.	-14 min.	11 min.	-9 min.
CS Part 3	50 min.	15 min.	-35 min.	22 min.	-28 min.
Total CS	**90 min.**	**37 min.**	**-53 min.**	**53 min.**	**-37 min.**
Post-test	15 min.	10 min.	-5 min.	10 min.	-5 min.
Total	**155 min.**	**100 min.**	**-55 min.**	**116 min.**	**-39 min.**