TECHNISCHE UNIVERSITÄT MÜNCHEN
Fakultät für Informatik
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A Comprehensive Competency Model and a Prototype Curriculum for Employees in Industry 4.0

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Vollständiger Abdruck der von der Fakultät für Informatik der Technischen Universität München zur Erlangung des akademischen Grades eines

Doktors der Naturwissenschaften (Dr. rer. nat.)

genehmigten Dissertation.

Vorsitzender: Prof. Dr. Hans-Joachim Bungartz

Prüfer der Dissertation:

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Die Dissertation wurde am 30.11.2020 bei der Technischen Universität München eingereicht und durch die Fakultät für Informatik am 05.07.2021 angenommen.

Zusammenfassung

Seit einigen Jahren können wir eine Entwicklung beobachten, die vielfach als „Digitale Transformation“ bezeichnet wird, und die uns im Ergebnis zu einer „Industrie 4.0“ führt. Das Synonym „Vierte Industrielle Revolution“ deutet darauf hin, dass diese Entwicklung, ähnlich wie die vorhergegangenen industriellen Revolutionen, einschneidende Veränderungen mit sich bringt. Neben disruptiven neuen Technologien eröffnet auch die neue Kombination bereits bekannter Technologien neue Handlungsmöglichkeiten – sowohl im privaten Bereich als auch in der Wirtschaft, beispielsweise mit dem Internet der Dinge/Internet of Things (IoT) oder der Entwicklung autonom fahrender Autos.

Dieser Prozess führt zu Veränderungen in allen Bereichen von Unternehmen. Beispielsweise fangen klassische Traditionsbetriebe an, statt ihrer Produkte nun Services zu verkaufen, welche die Nutzung ebendieser Produkte ermöglichen: z. B. Carsharing. Dieses verändert Geschäftprozesse, Geschäftsmodelle, und Geschäftsstrategien. Daher führt die Vierte Industrielle Revolution auch zu signifikanten Veränderungen von Arbeitsplätzen – und der Schaffung neuer Jobs. Möglicherweise ergeben sich hieraus neue Kompetenzprofile für Jobs in Industrie 4.0.

Es herrscht Einigkeit darüber, dass Arbeitnehmer über eine angemessene Qualifizierung verfügen müssen, um ihre Arbeit effektiv und effizient verrichten zu können. Um in einer Industrie 4.0-Arbeitswelt bestehen zu können, müssen Arbeitnehmer über entsprechende Fähigkeiten und Kompetenzen verfügen. Bisher gibt es gibt jedoch keine übergreifende Qualifizierungsstrategie oder ein übergreifendes Qualifizierungsprogramm.

Nach einem detaillierten Überblick über Industrie 4.0, die besonderen Kennzeichen und charakteristischen Technologien sowie der möglichen Konsequenzen, die sich aus Industrie 4.0 ergeben, beschäftigt sich die vorliegende Arbeit in drei Schritten mit dieser Forschungslücke. Zunächst werden Fähigkeiten und Kompetenzanforderungen für Arbeitnehmer in Industrie 4.0 identifiziert und analysiert. Es wird ein umfassendes Kompetenzmodell erarbeitet. Anschließend wird ein modulares Curriculum erstellt, mit dem diese Fähigkeiten und Kompetenzen in der Aus- und Weiterbildung vermittelt werden können. Lehrende und Lernende können dabei entscheiden, welche Module sie in ihrem spezifischen Kontext anwenden möchten – und so ihr individuelles Curriculum ableiten: Sie können auf der einen Seite zwischen verschiedenen Themen wählen, auf der anderen Seite zwischen unterschiedlichen Detailgraden und Schwierigkeitsstufen. Das Curriculum richtet sich an Studenten aus verschiedenen Fachrichtungen: Wirtschaftsinformatik, Informatik und Maschinenbau. Als drittes wird das Curriculum in verschiedenen Entwicklungsstadien und auf unterschiedlichen Detaillierungsstufen evaluiert. Evaluationsmechanismen sowohl für Lernerfolge als auch für Materialien des Curriculums werden vorgestellt.

Die vorliegende Arbeit trägt zu Theorie und Praxis bei, indem sie ein übergreifendes Kompetenzmodell für Arbeitnehmer in Industrie 4.0 bereitstellt. Dieses Kompetenzmodell kann in der Praxis im Personalmanagement unterstützen, beispielsweise bei der Erstellung neuer Stellenbeschreibungen, bei der Identifikation von Qualifizierungsbedarfen oder bei der Erarbeitung von Qualifizierungsprogrammen. Das evaluierte Industrie 4.0 Curriculum wird bereits produktiv eingesetzt und kann als Objekt für weitere Forschung herangezogen werden.

Schlagworte: Industry 4.0, Industrie 4.0, Vierte Industrielle Revolution, Industrial Internet, Internet der Dinge, Internet of Things, IoT, Kompetenzen, Fähigkeiten, Kompetenzanforderungen, Kompetenzmodell, Curriculum, Curriculumsentwicklung, Job Mining, Stellenanzeigen, Stellenanzeigenanalyse, Big Data, Smart Data, Sensoren

Summary

Today, we can observe a still ongoing process called "Digital Transformation", which leads us to an "Industry 4.0". The synonym "Fourth Industrial Revolution" indicates that this development goes along with significant changes – similar to the preceding industrial revolutions. Besides emerging disruptive technologies, new ways of combining already known technologies enable new ways of acting – in private live and in economy, e.g., with the Internet of Things (IoT) or the development of autonomous driving cars.

This process leads to changes in all areas of companies. E.g., former manufacturing companies start to offer services, which include the use of their products, instead of selling them: e.g., car sharing. This affects business processes, business models, and business strategies. Therefore, the Fourth Industrial Revolution leads to significant changes of jobs as well as the creation of new kinds of jobs. New competency profiles for employees in Industry 4.0 may emerge.

There is consensus that employees need to be qualified appropriately to fulfil their jobs effectively and efficiently. Therefore, they need to acquire appropriate skills and competencies to be prepared for the Industry 4.0 working environment. However, there is no comprehensive qualification strategy or programme for teaching these skills and competencies yet.

After providing a detailed overview of Industry 4.0, the characteristics and characteristic technologies as well as potential impacts of Industry 4.0, this thesis addresses this research gap in three steps. First, skill and competency requirements for employees in Industry 4.0 are identified and analysed. A comprehensive competency model is developed. Second, a modular-built curriculum for teaching these skills and competencies in higher and further education is developed. Trainers and learners can decide which modules to apply in their specific context and thus tailor their individual curriculum: They can choose between different topics on the one hand and different levels of detail and difficulty on the other hand. The curriculum addresses students from different fields: Information Systems, Business Informatics, Computer Sciences, Informatics, and Engineering. Third, the curriculum will be evaluated at different development stages and at different levels of detail. Evaluation mechanisms for evaluating both, learning outcomes and the materials of the curriculum chosen for a class will be provided.

The presented work contributes to theory by offering a comprehensive competency model for employees in Industry 4.0. It contributes to practice as the competency model can serve to support human resource management, e.g., the creation of new job descriptions, identification of qualification needs, or the implementation of qualification programmes. The evaluated curriculum for building up Industry 4.0 competencies is already in use in practice and may be subject to further research.

Keywords: Industry 4.0, Industrie 4.0, Fourth Industrial Revolution, Industrial Internet, Internet of Things, IoT, Competencies, Skills, Competency Requirements, Competency Model, Curriculum, Curriculum Development, Job Mining, Job Offers, Job Offers Analysis, Big Data, Smart Data, Sensors

Table of Contents

List of Figures

List of Tables

List of Abbreviations

Abbreviation	Meaning
acatech	Deutsche Akademie der Technikwissenschaften e.V. (German National Academy of Science and Engineering)
ACM	Association for Computing Machinery
ACMT	ACM Transaction Journals (Journals)
AG	Aktiengesellschaft (German: → PLC, Public Limited Company)
AI	Artificial Intelligence
AIS	Association for Information Systems
AISeL	AIS Electronic Library
ARCS	Attention, Relevance, Confidence, Satisfaction
ASME	American Society of Mechanical Engineers
bat	Batch
BDI	Bundesverband der Deutschen Industrie e.V. (Federation of German Industries)
BI	Business Intelligence
BIS	Business Information System
BISE	Business and Information Systems Engineering
Bitkom	Bundesverband Informationswirtschaft, Telekommunikation und neue Medien e.V.(German Association for IT, Telecommunications and New Media, registered association)
BLOB	Binary Large Object
BMBF	Bundesministerium für Bildung und Forschung (German Federal Ministry of Education and Research)
BOM	Bill of Materials
BPM	Business Process Management
B.V.	Besloten Vennootschap met Beperkte Aansprakelijkheid (→ Dutch version of a private LLC)
B2B	Business-to-Business
B2C	Business-to-Customer
CACM	Communications of the Association for Computer Machinery (Journal)
CEB	Former technology company, now belonging to Gartner.
CEO	Chief Execution Officer
CGUL	Custom Grouper User Language
CIS	Course Interest Survey
CIT	Critical Incident Technique
CO	Controlling (SAP module)
Co.	Compagnie (→ GmbH & Co. KG)

CPSS	Cyber-Physical Service System
CPS	Cyber-Physical System
CPU	Central Processing Unit
CRM	Customer Relationship Management
CRM	Customer Relationship Management (SAP module)
CS	Customer Service (SAP module)
CV	Curriculum Vita
DACH	DACH region: D – Deutschland (Germany), A – Austria (Latin name), CH – Confoederatio Helvetica (Switzerland, Latin name
DB	Database
DeSeCo	Definition and Selection of Competencies
DFKI	Deutsches Forschungszentrum für Künstliche Intelligenz GmbH (German Research Center for Artificial Intelligence, German GmbH)
DIHK	Deutscher Industrie- und Handelskammertag (German Chambers of Commerce and Industry)
DOAS	Department of Administrative Services
DSS	Decision Support Systems (Journal)
EaaS	Education as a Service
EAM	Enterprise Asset Management (SAP module)
ECIS	European Conference on Information Systems (Conference)
EIS	Enterprise Information System
EJIS	European Journal of Information Systems (Journal)
EM	Electronic Markets (Journal)
EMEA	Europe, Middle East, Africa
ERP	Enterprise Resource Planning
e.V.	Eingetragener Verein (→ German Registered Association)
FB	Fachbereich (→ Department)
FB WI GI	Fachbereich Wirtschaftsinformatik der Gesellschaft für Wirtschaftsinformatik e.V. (Department for Business Informatics of the German Society for Computer Sciences)
FI	Financial Accounting
FIFA	Fédération Internationale de Football Association
Fraunhofer IML	Fraunhofer Institut für Materialfluss und Logistik (Fraunhofer Institute for Material Flow and Logistics)
GB	Gigabyte
GBI	Global Bike Inc., virtual company for training issues
GBS	Global Bike Services
gGmbH	Gemeinnützige Gesellschaft mit beschränkter Haftung (limited company operating as public utility)

GI	Gesellschaft für Informatik e.V. (German Society for Computer Sciences)
GmbH	Gesellschaft mit beschränkter Haftung (German: → LLC, Limited Liability Company)
GmbH & Co. KG	Gesellschaft mit beschränkter Haftung & Compangnie Kommanditgesellschaft (German: limited partnership with a limited liability company as general partner; → GmbH, → Co., → KG)
GUI	Graphical User Interface
HCI	Human-Computer Interaction
HCI	Human-Computer Interaction (Journal)
HCM	Human Capital Management
HCM	Human Capital Management (SAP module)
HPI	Hasso-Plattner-Institut für Digital Engineering gGmbH (Hasso Plattner Institute)
HR	Human Resources
HTML	Hypertext Markup Language
ICIS	International Conference on Information Systems
ICT	Information and Communication Technology
IDE	Integrated Development Environment
IE	Internet Explorer
IE	Information Extraction
IEEE	Institute of Electrical and Electronics Engineers
IEEET	IEEE Transaction Journals (Journals)
IJIM	International Journal of Information Management (Journal)
IKT	Informations- und Kommunikationstechnologie (Information and Communication Technology)
IMMS	Instructional Materials Motivation Survey
Inc.	Incorporated
INFSJ	Informing Science Journal (Journal)
iOS	iPhone OS; mobile operating system developed by Apple Inc.
IoT	Internet of Things
IoTS	Internet of Things and Services
IS	Information Systems/Informationssysteme
ISJ	Information Systems Journal (Journal)
ISR	Information Systems Research (Journal)
ISYS	Information Systems (Journal)
IT	Information Technology/Informationstechnologie
I&M	Information & Management
I&O	Information and Organization (Journal)
JAIS	Journal of the Association of Information Systems (Journal)

JMIS	Journal of Management Information Systems (Journal)
JIT	Journal of Information Technology (Journal)
JSIS	Journal of Strategic Information Systems (Journal)
KG	Kommanditgesellschaft (German: Limited partnership)
KMU	Klein- und mittelständische Unternehmen (German: → SME, Small and Medium-Sized Enterprises)
LLC	Limited Liability Company
LTS	Long Term Support
LU	Learning Unit
MB	Megabyte
MES	Manufacturing Execution System
MIS	Management Information System
MISQ	Management Information Systems Quarterly (Journal)
MM	Materials Management (SAP module)
MOOC	Massive Open Online Course
MS	Microsoft
MS	Management Science (Journal)
M2M	Machine-to-Machine
NER	Named Entity Recognition
NLP	Natural Language Processing
OECD	Organisation for Economic Co-Operation and Development
OLAP	Online Analytical Processing
OLTP	Online Transactional Processing
OS	Organization Science (Journal)
OVGU	Otto-von-Guericke-Universität, Mageburg, Germany
PAL	Predictive Analytics Library
PDF	Portable Document Format
PIAAC	Programme for the International Assessment of Adult Competencies
PISA	Programme for International Student Assessment
PCL	Public Limited Company
POS	Part-of-Speech
PoV	Point of View
PP	Production Planning (SAP module)
PPT	Microsoft (MS) PowerPoint
PS	Project System (SAP module)
PSS	Product-Service System
PWC	PricewaterhouseCoopers (consulting company)
QM	Quality Management
QM	Quality Management (SAP module)

QR(-Code)	Quick Response (Code)
RAM	Random Access Memory
RFID	Radio-Frequency Identification
ROI	Return on Investment
RQ	Research Question
S.A.	Société Anonyme
SAP BW	SAP Business Warehouse
SAP BW/4HANA	SAP BW for HANA
SAP CRM	SAP Customer Relationship Management
SAP ERP	SAP Enterprise Resource Planning
SAP SCM	SAP Supply Chain Management
SAP S/4HANA	SAP Business Suite for HANA
SAP UA	SAP University Alliances
SAP UCC	SAP University Competence Center
SAPUI5	SAP User Interface 5
SCM	Supply Chain Management
SD	Sales and Distribution (SAP module)
SE	Societas Europaea
SHL	A technology company
SMAC	Social, Mobility, Analytics, Cloud
SME	Small and Medium-Sized Enterprises
SOC	Service-Oriented Computing (→HPI – Future SOC Lab)
SPS	Service Pack Stack
TA	Text Analysis
TB	Terabyte
TM	Text Mining
TUM	Technische Universität München (→ Technical University of Munich, Munich, Germany)
UAE	United Arab Emirates
UCF	Universal Competency Framework
UK	United Kingdom
US	United States (of America) (→ USA, United States of America)
URL	Uniform Resource Locator
USA	United States of America (→ US, United States (of America))
UX	User Experience
VDI	Verband Deutscher Ingenieure, Association of German Engineers
VDMA	Verband Deutscher Maschinen- und Anlagenbau e.V. (German association of manufacturing systems engineering and plant engineering and construction (translated by the author), registered association)

VW	Volkswagen (German car manufacturer and car brand)
WI	Wirtschaftsinformatik (German: Business Informatics, Information Systems)
WI	Wirtschaftsinformatik (Conference)
WI	Wirtschaftsinformatik (Journal)
WKWI	Wissenschaftliche Kommission Wirtschaftsinformatik im Verband der Hochschullehrer für Betriebswirtschaft e.V. (German scientific committee for Business Informatics in the association of the professors for economics (translated by the author), registered association)
WM	Warehouse Management
WM	Warehouse Management (SAP module)
XML	Extensible Markup Language
z.B.	Zum Beispiel (German: e.g.)
ZIP	File format, abbreviation from “zipper”
ZVEI	Zentralverband Elektrotechnik- und Elektronikindustrie e.V. (Germany’s Electrical Industry, registered association)

1 Introduction

"Digitization will create new jobs, but it will also eliminate old ones – mostly unskilled ones. We have seen that in every structural transition to date. If the net balance is to add more jobs, we must concern ourselves with qualifications. Our goal must be to take people with us on our journey by providing them with training and development."

Henning Kagermann, President acatech, in: Roland Berger Strategy Consultants and BDI Bundesverband der Deutschen Industrie e.V. (2015, p. 41).

As co-founder and former management board member of SAP SE and president of the Deutsche Akademie der Technikwissenschaften e.V. (acatech)[1], Henning Kagermann is leading the German Nationale Plattform Elektromobilität[2]. He is part of the German working team on Industrie 4.0[3], which supports the German Federal Government, and of the German Forschungsunion Wirtschaft – Wissenschaft[4] of the Federal Ministry of Education and Research, which enhances the German Hightech-Strategy 2020. Thus, he is one of the leaders of the German vision of Industrie 4.0 (Wikipedia, 2018). In this quotation, he emphasizes that digitization – which is one of the main characteristics of Industry 4.0 – will change jobs in the working world significantly. He underlines the importance of qualifying employees to keep them able and willing to work in the changed working environment. Thus, it may be worthwhile to have a closer look at training and qualification for the emerging topics of digitization and Industry 4.0. This is supported by another quote from acatech in which the authors anticipate benefits from Industry 4.0 for different kinds of enterprises:

"Von Industrie 4.0 ist ein Nutzen sowohl für große Unternehmen als auch für kleine und mittlere Unternehmen (KMU) zu erwarten. Gleichzeitig transformiert Industrie 4.0 die Arbeitswelt nachhaltig. Die zunehmende Vernetzung, Flexibilität und Komplexität der Prozesse stellen neuartige Anforderungen an die Kompetenzen in Unternehmen und die Qualifikation der Mitarbeiterinnen und Mitarbeiter. Zudem verändern sich durch Industrie 4.0 auch die Strukturen und Organisationsformen in den Betrieben sowie die Gestaltung von Arbeitsplätzen."[5]

[1] Deutsche Akademie der Technikwissenschaften e.V. (acatech): German National Academy of Science and Engineering, registered association.

[2] Nationale Plattform Elektromobilität: National Platform for Electro Mobility.

[3] "Industrie 4.0": German diction.

[4] Forschungsunion Wirtschaft – Wissenschaft: Research Union Economy – Science.

[5] Industry 4.0 is expected to lead to benefits for both, large enterprises as well as for small and medium-sized enterprises (SME). Simultaneously, Industry 4.0 is transforming the world lastingly. The increasing degree of cross-linking, flexibility, and complexity of processes leads to novel requirements for competencies in enterprises as well as for qualification of employees. Moreover, Industry 4.0 will result in changes of structures and organization forms in companies as well as in changes of workplace design. Translated by the author.

acatech, in: Plattform Industrie 4.0 - Wissenschaftlicher Beirat, Fraunhofer IML, and Deutsche Akademie der Technikwissenschaften (acatech) (2016, p. 4).

Following these statements, it seems to be necessary to adjust education and qualification to prepare (future) employees for the challenges of Industry 4.0. Therefore, this thesis deals with the implications of Industry 4.0 on skill and competency requirements for (future) employees. We offer a competency model for employees in Industry 4.0. Based on that, a prototype curriculum for Industry 4.0 is presented.

1.1 Motivation and Relevance

The world is facing major changes in technology that will significantly influence our lives – including our working world. The technological progresses in different areas enable us to use technologies today that have only been fiction just a few years ago. Examples are smart glasses, which create a virtual reality (Berg, Vance, 2017), sensor technologies, which enable the development of autonomous driving cars (Lambert, 2016), fitness watches (Anderl et al., 2015), real-time translators (Shankland, 2016), or the blockchain technology (D. Hoffmann, 2017). Kurzweil (2015) states that the technological progress will no longer be linear in the digital era, but exponential.

The currently evolving or emerging, partly even disruptive technologies lead to a higher digitization and to the development of new products and services. Not only production processes are changing with the introduction of smart and connected machines; business processes, models and strategies are affected by the increasing digitization as well. Some people refer to this development as Fourth Industrial Revolution, "Industry 4.0", or the "Industrial Internet". The term "Industrie 4.0"[6] first evolved in the scope of the Hightech Strategy of the German Federal Government (Die neue Hightech-Strategie, 2014; Sendler, 2013), an initiative with the goal of preparing the German Industry for the future (A. Roth, 2016). The English term "Industry 4.0" is used increasingly (e.g., "Industry 4.0": about 810,000 hits on Google Scholar[7] on March 6th, 2017, about 1,130,000 hits on April 10th, 2018, about 3,260,000 hits on July 19th, 2021). Thus, the English diction will be used in the following – except in citations or when the German origin of "Industrie 4.0" should be emphasized.

In the past, industrial revolutions have changed the way we live and work significantly several times:

- The First Industrial Revolution invented new manufacturing processes and machines.
- The Second Industrial Revolution is characterized by the invention of mass production.
- The Third Industrial Revolution is called the electronic revolution and came along with digitization and computers.

[6] German diction.
[7] Google Scholar: https://scholar.google.de/. Accessed on July 19th, 2021.

The Internet of Things (IoT), Smart Factories, cyber-physical systems (CPS), and the increased use of embedded systems are crucial aspects of Industry 4.0 (Die neue Hightech-Strategie, 2014). Like the revolutions before, this Fourth Industrial Revolution will have a huge impact on our daily lives and our working world in all its dimensions (Bundesministerium für Arbeit und Soziales – Abteilung Grundsatzfragen des Sozialstaats der Arbeitswelt und der sozialen Marktwirtschaft, 2015; Gebhardt, Grimm, Neugebauer, 2015; Kagermann, Wahlster, Helbig, 2013). As operating production machines will be more automated then before, the tasks of employees will switch from operating to supervising activities:

> In an *"intelligent company the employees supervise the flexible manufacturing process with devices for the computer based reality perception (augmented reality devices like tablets or smart glasses), the employees immediately react if problems or process changes appear and the employees are assisted by fine sensory robot units"* (Gebhardt et al., 2015, p. 120).

Employees need to be are prepared with mind-sets and a wide range of competencies that allow them to apply new tasks and new kinds of jobs (Deutsche Akademie der Technikwissenschaften (acatech), Fraunhofer IML, equeo GmbH, 2016; Smit, Kreutzer, Moeller, Carlberg, 2016; Zukunftsprojekt Industrie 4.0, 2016).

> *"The requirements for the digitized skilled work will rise because the processes are interconnected and more complex, particularly with reference to the overlap of technical, organizational and social spheres of activity and the work processes in the company"* (Gebhardt et al., 2015, p. 121).

Not only these examples indicate that competency profiles for employees will change significantly (Richert et al., 2016). While automation will replace labour workforce, jobs relying on competency profiles that require a higher education will increase (Kagermann et al., 2013; Polchow, 2017; Vogel, 2017). Training on specific enterprise information systems (EIS) will not be sufficient anymore as the overview of company-wide and cross-company processes becomes significantly more important. Besides an overview of emerging technologies, employees will need a broader overview and a general understanding of company processes and connections. Another important aspect of Industry 4.0 is a huge amount of data, which is generated by sensors, social media, etc. Big data – or smart data – is becoming a valuable asset, where data represents the raw material that companies have to process and analyse in order to extract business value from it.

Hofmann (2016) states that the implementation of Industry 4.0 in a company depends, among other things, on the preparation of employees, e.g., through qualification. Qualifying employees for working in Industry 4.0 is a challenge for companies as well as for education and training providers. Today, companies already face difficulties in finding staff qualified and prepared for Industry 4.0 (Baygin, Yetis, Karakose, Akin, 2016; Brendle, Stamm, Sibold, Vogel, 2016; IT-Trends 2020, 2015). Digitalpotenzial Liegt Brach (2017) gives an overview of the maturity of companies regarding the Digital Transformation. It shows that 67% of the companies are “Digital Beginners” (40%) or even “Digital Deniers” (27%) – while only 32 % are “Digital Performers” (cp. Figure 1).[8]

		My company is working systematically and continuously on its digital transformation		
		Yes	**No**	
Our IT setup fulfils the requirements of the digital transformation	**Yes**	**Digital Performers (32%)**	**Digital Magicians (1%)**	**33%**
	No	**Digital Beginners (40%)**	**Digital Deniers (27%)**	**67%**
		72%	**28%**	

Figure 1: Maturity of Companies Regarding the Digital Transformation (with regards to Digitalpotenzial Liegt Brach (2017))

When we started our work in 2016, there was no competency model for Industry 4.0. Structured data regarding competency requirements of German companies was missing (Deutsche Akademie der Technikwissenschaften (acatech) et al., 2016). Most companies still did not have the knowledge needed for providing their employees with the skills and competencies required for Industry 4.0 in-house. At the same time, there was a lack of (external) training tailored and offered to prepare employees for Industry 4.0. This was a serious issue, as it is a well-recognized and long-known fact that untrained employees may refuse to or fail in using new technologies and processes – which may result in competitive disadvantages or failures, e.g., of IT projects (Compeau, Olfman, Sei, Webster, 1995).

This thesis addresses the challenge of missing competency profiles for Industry 4.0 and corresponding training materials. In the scope of this work, we develop a comprehensive competency model for Industry 4.0. Based on this model, we implement a modular-built curriculum for teaching skills and competencies needed in Industry 4.0. As Industry 4.0 affects huge areas of industry, trainers and learners can decide which modules to apply in their specific context. They can choose between different topics, e.g., “Strategy and Business Models”, “IoT: Integrating Sensors”, or “Big Data Analytics” – and predefined learning journeys at different levels of detail and difficulty, e.g., an overview or a deep dive into a topic. The curriculum is designed this way to meet the different needs of learners at different levels of detail. Lasi, Fettke, Kemper, Feld, and Hoffmann (2014a, 2014b) point out that “the approaches and ideas in the context of “Industry 4.0” are situated at the interfaces of the disciplines [of] [E]lectrical [E]ngineering, [B]usiness [A]dministration, [C]omputer [S]cience[s], [B]usiness and [I]nformation [S]ystems [E]ngineering, and [M]echanical [E]ngineering as well as the participating segments” (Lasi, Fettke, et al., 2014b, p. 240). Therefore, the curriculum covers topics relevant in the areas of Economics, Information Systems (IS), Business Informatics, Computer Sciences, Informatics, and Engineering. Additionally, the curriculum contains mechanisms for evaluating the learning

[8] Digital Potential Lies Idle. Translated by the author.

outcomes. During the development process, several parts of the curriculum are subject to evaluations on different levels. The comprehensive Industry 4.0 curriculum pilot may serve as subject for future research. Applying the curriculum will show, whether a curriculum with content that can be combined flexibly as well as interactive elements will be accepted by the teaching and learning community.

1.2 Research Objective and Research Questions

Our first goal is to address the research gap that there is no comprehensive competency model for employees in Industry 4.0. Therefore, we develop and evaluate such a model, which may serve as basis to further research lateron. The competency model is relevant for practitioners as well, as it may be used to identify future qualification requirements – or to derive and develop new job profiles.

Second, we develop and present a prototype curriculum for education and training in the area of Industry 4.0, based on our competency model for employees in Industry 4.0. This curriculum can be used in practice to teach students Industry 4.0 topics. It may serve as subject for further research as well.

This thesis is structured by the following three research questions (RQ):

RQ1: Which skills and competencies do employees need in an Industry 4.0 environment?

RQ2: How can competencies for Industry 4.0 be implemented in learning units for (future) employees following best-practice design guidelines?

RQ3: Does the proposed prototype curriculum meet the needs of its consumers?

1.3 Structure of this Thesis

The goal of this work is to answer the RQs entitled in section 1.2 by considering theoretical and practical findings as described in detail in chapter 3. Therefore, the thesis is structured as follows (cp. Figure 2):

Chapter 1: "Introduction": This chapter starts with introducing and motivating the topic and proving its relevance. The research gap, the research objective and the research questions are introduced. The overall structure of the thesis is presented.

Chapter 2: "Terminologies and Theoretical Background": This chapter provides the reader with the introduction to the central terminologies and theoretical background of the topics at hand, mainly Industry 4.0 and related topics as well as the terms of competencies and curricula. If necessary, the scope of terms as used in the course of this work is defined and the reader is provided with clear definitions of the terms and concepts as used in this thesis.

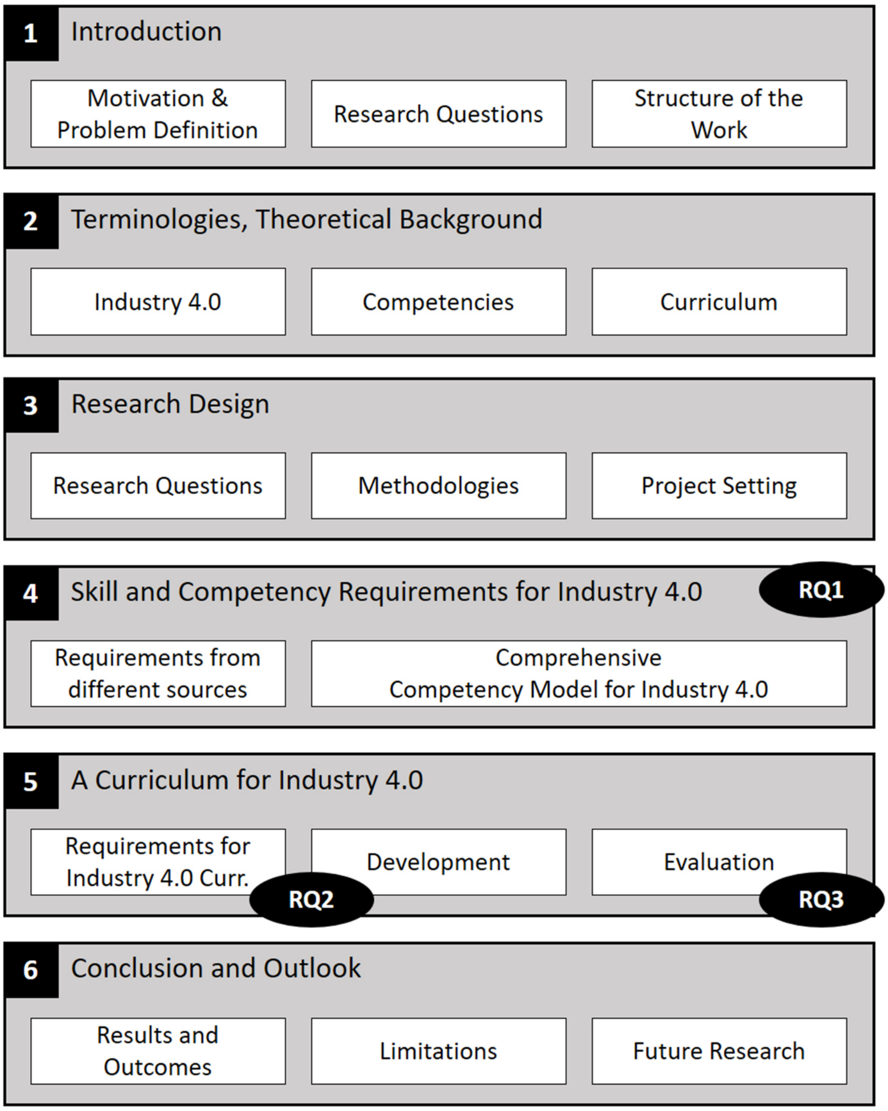

Figure 2: Structure of this Thesis

Chapter 3: "Research Design": In this chapter, the research design that structures this thesis is presented. The RQs are introduced in more detail. The applied methods and approaches are presented and tailored to fit the needs of this work. The project setting of the development project for the prototype Industry 4.0 curriculum (cp. chapter 4) is described.

Chapter 4: "Skill and Competency Requirements for Industry 4.0": In this chapter, the first RQ is answered. Using several sources of information such as scientific literature, focus groups with personnel from academia, and text mining (TM) on job offers, skills and competency requirements for Industry 4.0 are derived and analysed in two major iterations. As result, a comprehensive competency model for employees Industry 4.0 is presented.

Chapter 5: "A Curriculum for Teaching Relevant Skills and Competencies for Industry 4.0": This chapter answers the second and third RQ. A prototype Industry 4.0 curriculum for providing skills and competencies for Industry 4.0 is developed based on the former results of this work. Evaluations takes place at several stages of the curriculum development process.

Chapter 6: "Conclusion and Outlook": In this chapter, an overview of the results and limitations of this work is given. Topics for future research are revealed. Implications for research and practice are outlined.

1.4 Related Work

This thesis was written at the chair for Information Systems of Prof. Dr. Helmut Krcmar at the Technical University of Munich (TUM). The prototype curriculum for Industry 4.0, which is subject to RQs 2 and 3, was developed in a project (cp. section 3.8.1) conducted in the research team SAP University Competence Center (SAP UCC; cp. section 3.8.1.1) at the chair of Prof. Dr. Helmut Krcmar. In the scope of this research project, this PhD thesis, the PhD thesis of Dr. Loina Prifti (Prifti, 2019) and the master thesis of Sebastian Hagn, M.A. (Hagn, 2017) were written. Both PhD theses use the same Industry 4.0 curriculum as research object. Thus, there are some overlappings. However, both PhD theses focus on different aspects. In (Prifti, 2019), (Prifti, Knigge, Kienegger, Krcmar, 2017a), and (Prifti, Knigge, Kienegger, Krcmar, 2017b), a competency model for Industry 4.0 is developed based on findings from scientific literature and focus groups with experts from academia. The approach and the findings are mentioned in this work as well. The competency model presented as outcome of RQ1 is complemented and verified with findings from practice, namely from the analysis of job offers for Industry 4.0, a work which was supported by Hagn (2017).

Publications connected with this PhD are listed below:

- Knigge, M., Prifti, L., Hecht, S., Krcmar, H.: Follow-Up Project: Automated Text Mining on Job Offers Using SAP HANA: Analyzing Skill and Competency Requirements for Industry 4.0. Hasso Plattner Institut (HPI) – Future SOC Lab[9], unpublished. (Knigge, Prifti, Hecht, Krcmar).
- Knigge, M., Willnecker, F., Neumer, T., Krcmar, H.: Final Project Report: Applying Text Mining on Job Offers and Curricula Vitae Using SAP HANA: Analyzing Skill and Competency Requirements for Industry 4.0. HPI – Future SOC Lab[10], 2020. (Knigge, Willnecker, Neumer, Krcmar, 2020).
- Knigge, M., Prifti, L., Hecht, S., Krcmar, H.: Text Mining on Job Offers Using SAP HANA: Analyzing Skill and Competency Requirements for Industry 4.0. HPI Future SOC Lab, 2020. (Knigge, Prifti, Hecht, Krcmar, 2020).
- Prifti, L.: Professional Qualification in "Industrie 4.0": Building a Competency Model and Competency-Based Curriculum. Technical University of Munich, 2019. (Prifti, 2019)
- Prifti, L., Levkovskyi, B., Knigge, M., Krcmar, H.: Developing an Evaluation Model for Information Systems Curricula. Multikonferenz Wirtschaftsinformatik (MKWI), 2018. (Prifti, Levkovskyi, Knigge, Krcmar, 2018).

[9] HPI. Hasso-Plattner-Institut für Digital Engineering gGmbH: German IT faculty of the University of Potsdam, in Potsdam, Germany. https://hpi.de/. Accessed on July 19th, 2021.
[10] HPI. Hasso-Plattner-Institut für Digital Engineering gGmbH: German IT faculty of the University of Potsdam, in Potsdam, Germany. https://hpi.de/. Accessed on July 19th, 2021.

- Prifti, L., Knigge, M., Kienegger, H., and Krcmar, H.: A Competency Model for "Industrie 4.0" Employees. Wirtschaftsinformatik (WI), 2017. (Prifti, Knigge, Kienegger, et al., 2017a).
- Prifti, L., Knigge, M., Kienegger, H., and Krcmar, H.: Un modello di competenze per i lavoratori di Industria 4.0. Professionalità Studi 1(1), 2017. (Prifti, Knigge, Kienegger, et al., 2017b).
- Master thesis: Hagn, S.: Automatische Extraktion von Bewerberanforderungen aus Stelle-nanzeigen im Kontext Industrie 4.0 mit SAP HANA. Technical University of Munich, 2017. (Hagn (2017), supervised by Krcmar, H., advised by Knigge, M. and Prifti, L.).
- Prifti, L., Knigge, M., Löffler, A., Hecht, S., Krcmar, H.: Emerging Business Models in Education Provisioning: A Case Study on Providing Learning Support as Education-as-a-Service. International Journal of Engineering Pedagogy (IJEP) 7(3), 2017. (Prifti, Knigge, Löffler, Hecht, Krcmar, 2017).
- Knigge, M., Prifti, L., Hecht, S., and Krcmar, H.: Text Mining on Job Offers Using SAP HANA: Analyzing Skill and Competency Requirements of "Industry 4.0". Wirtschaftsinformatik (WI), 2017, (Knigge, Prifti, Hecht, Krcmar, 2017).
- Documents published with the first release of the curriculum "The Digital Transformation of Global Bike": SAP UCC Munich: Project Curriculum Development (2016 - 2017).

2 Terminologies and Theoretical Background

This chapter contains the introduction of central terminologies and the theoretical background of the topics of this work, mainly Industry 4.0, skills and competencies, and curricula as well as curriculum development. If appropriate, the scope of terms as used in the course of this work is defined.

2.1 Information Systems

The Wissenschaftliche Kommission Wirtschaftsinformatik im Verband der Hochschullehrer für Betriebswirtschaft e.V. (WKWI)[11], the Fachbereich (FB) Wirtschaftsinformatik (WI) of the German Gesellschaft für Informatik e.V. (GI)[12], and the Department for Business Informatics and IS of the German Gesellschaft define "Information Systems" (IS)[13] as follows:

> *"IS sind soziotechnische Systeme, die menschliche und maschinelle Komponenten (Teilsysteme) umfassen. Sie unterstützen die Sammlung, Strukturierung, Verarbeitung, Bereitstellung, Kommunikation und Nutzung von Daten, Informationen und Wissen sowie deren Transformation. IS tragen zur Enscheidungsfindung, Koordination, Steuerung und Kontrolle von Wertschöpfungsprozessen sowie deren Automatisierung, Integration und Virtualisierung unter insbesondere ökonomischen Kriterien bei. IS können Produkt-, Prozess- und Geschäftsmodellinnovationen bewirken."*[14]
> (Wissenschaftliche Kommission Wirtschaftsinformatik im Verband der Hochschullehrer für Betriebswirtschaft e.V. (WKWI), Fachbereich Wirtschaftsinformatik der Gesellschaft für Informatik e.V. (GI FB WI), 2011, p. 1).

This wide definition of IS comprises not only software applications, but also every component that is needed to run and use the software and. An overview of the components of IS concerning this definition is presented in Figure 3. Due to Krcmar (2015a), the term of IS includes IS as well as communication systems. IS that are used in companies, are also known as enterprise information systems (EIS) or business information systems (BIS). Hevner et al. (2004) emphasize other, more organizational and strategical aspects of IS. They underline that "organizations and the information systems that support them are among the most complex artefacts designed by human intention" (Hevner et al., 2004, p. 3). They stress that "[t]he effective transition of

[11] Wissenschaftliche Kommission Wirtschaftsinformatik im Verband der Hochschullehrer für Betriebswirtschaft e.V. (WKWI): German scientific committee for the subjects of study Business Informatics and IS (German: "Wirtschaftsinformatik" (WI)), part of the association of professors for Business Administration, registered association. http://wi.vhbonline.org/.

[12] Fachbereich Wirtschaftsinformatik of the German Gesellschaft für Informatik e.V. (FB WI GI): Department for Business Informatics and IS of the German society for Informatics, registered association. https://fb-wi.gi.de/.

[13] Information systems (IS): German: Informationssysteme (IS). If not explicitly mentioned differently, IS refers to information systems (applications) in this thesis, not to the subject of study.

[14] IS are socio-technical systems comprising human and machine components (part systems). They support the collection, structuring, processing, allocation, communication and usage of data, information, and knowledge, as well as their transformation. IS have a share in decision making, coordination, management, and controlling of value-added processes as well as their automation, integration, and virtualization, especially considering economic criteria. IS may cause product, process and business model innovations. Translated by the author.

strategy into infrastructure requires extensive design activities on both sides of the figure – organizational and technological" (Hevner et al., 2004, p. 3). This correlation between strategy and IS infrastructure is illustrated in Figure 4.

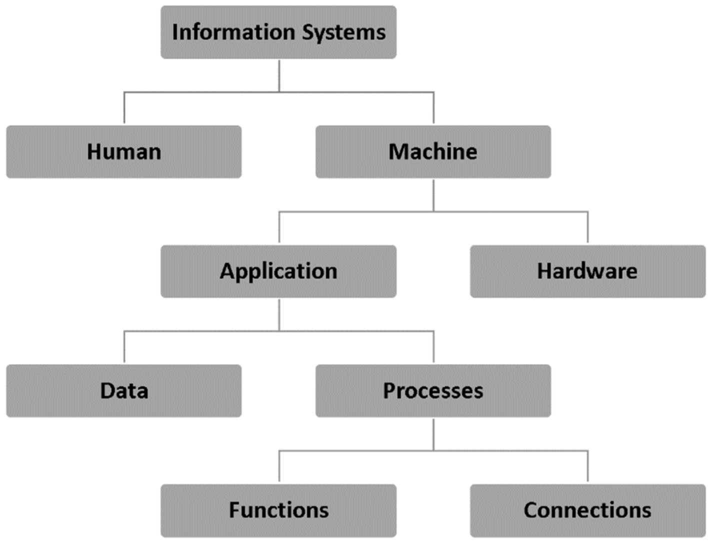

Figure 3: IS as Human-Machine-Systems (with regards to Krcmar (2015a, p. 22))

We can conclude that, IS are complex systems that do not only comprise or affect software or hardware, but also the people and organizations working with them. Examples for IS are enterprise resource planning (ERP) systems, management information systems (MIS), or data warehouses.

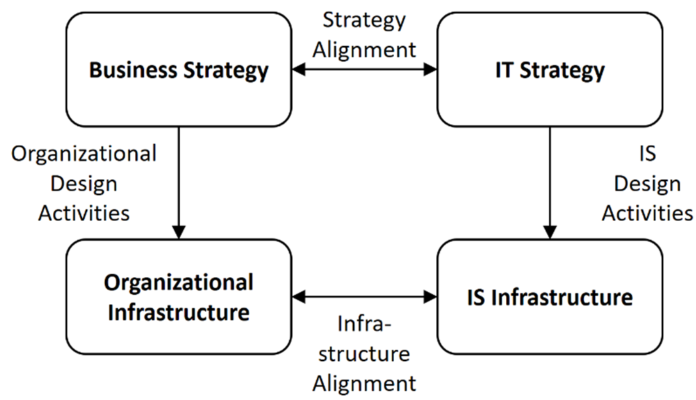

Figure 4: Business and IT Strategy, Organizational and IS Infrastructure (with regards to Hevner et al. (2004, p. 4))

Technically, EIS have been divided into two classes for more than 25 years: online transactional processing (OLTP) systems and online analytical processing systems (OLAP) systems (Plattner, 2012). OLTP comprises transaction-based, dialog-oriented data processing (Taschenbuch der Informatik, 2001). OLAP focusses on analytical operations on databases (DBs) (Taschenbuch der Informatik, 2001). Due to the different purposes, the main transaction type with OLTP is write and read, while it is only read with OLAP. This gave rise to the idea, that the two kinds of processing needed to be supported by different technologies, so OLTP and OLAP functionalities were separated into different kinds of systems and architectures. E.g., traditional ERP systems are typical examples for OLTP systems, whereas reporting systems such as data warehouses are typical examples for OLAP systems. Consequently, huge amounts of data had to be transferred between OLTP systems, where the data was generated and processed – and OLAP systems, where the data was analysed and prepared for reporting.

Plattner (2012) analysed the occurrence of read- and write transactions in typical OLTP and OLAP systems. He concluded that the transactions do differ much less than expected. Together with the development of in-memory DBs, he proposes to dispense with the differentiation between OLTP and OLAP systems (Plattner, 2012) (cp. section 2.3.1.3).

2.2 The Fourth Industrial Revolution/Industry 4.0/the Digital Transformation and Related Concepts

Besides the term “Industrie 4.0”and the English translation “Industry 4.0”, there are other terms prominent in English speaking countries such as “Industrial Internet” or “Internet of Things”/“IoT” which refer to the same phenomenon – or to certain aspects of it (cp. section 2.2.3). In this section, different definitions are given and compared. It is defined, what understood when speaking of “Industry 4.0” in the scope of this work.

A. Roth (2016) presents a well-formulated, comprehensive definition for Industry 4.0:

> *“Industrie 4.0 umfasst die Vernetzung aller menschlichen und maschinellen Akteure über die komplette Wertschöpfungskette sowie die Digitalisierung und Echzeitauswertung aller hierfür relevanten Informationen, mit dem Ziel die Prozesse der Wertschöpfung transparenter und effizienter zu gestalten, um mit intelligenten Produkten und Dienstleistungen den Kundennutzen zu optimieren.”* (A. Roth, 2016, p. 6)[15].

Industry 4.0 is as well referred to as the Fourth Industrial Revolution (Bundesverband Informationswirtschaft Telekommunikation und neue Medien e.V. (Bitkom), Verband Deutscher Maschinen- und Anlagenbau e.V. (VDMA), (ZVEI), 2016). Each industrial revolution was based on technological development and led to a shift in paradigm (Lasi, Fettke, et al., 2014a, 2014b). In order to give an impression of the significance and the impact of industrial revolutions on live and work, a historical overview of the previous industrial revolutions is given before a closer look on definitions of Industrie 4.0/Industry 4.0 is presented.

2.2.1 History of Industrial Revolutions – the Fourth Industrial Revolution and the Development of the Term “Industrie 4.0”

The First Industrial Revolution started in 1750: It came along with new manufacturing processes and machines. It is also called “mechanization” (Lasi, Fettke, et al., 2014b, p. 239). This industrialization, mainly in textile, iron, and steel industries, was based on the emerge of water and steam engines (Bauernhansl, ten Hompel, Vogel-Heuser, 2014; Siepmann, Graef, 2016). The transportation system improved as well as the output of basic goods production, which finally led to a high increase of the population (Bauernhansl et al., 2014). People searching for work moved from the countryside into the cities (Bauernhansl et al., 2014). However, they split up into two classes: factory workers and factory owners.

The Second Industrial Revolution took place around 1870. It was characterized by the invention of mass production and the division of labour. Electrical energy, assembly lines, electric drives, and combustion engines including the use of oil have been the most important inventions of

[15] Industry 4.0 comprises the integration of all human and machine actors along the complete value chain as well as the digitization and real-time analysis of all relevant information with the goal to design value chain processes more transparent and more efficient in order to optimize the customer value with intelligent products and services. Translated by the author.

this revolution (Bauernhansl et al., 2014; Kaufmann, 2015; Siepmann, Graef, 2016). Large-scale industrial mass production enabled the progression in chemical, electrical, engineering, and automotive industries (Bauernhansl et al., 2014).

The Third Industrial Revolution, which started in the early 1960s, is called the "electronic revolution" – or "digitalization [sic!]" (Lasi, Fettke, et al., 2014b, p. 239). It affected our lives with the invention of electronics, later resulting into the information and communication technology (ICT), and, of course, the internet. This enabled the automation of production (Bauernhansl et al., 2014; Kaufmann, 2015; Siepmann, Graef, 2016). Customer requirements became more individual and differentiated after the markets were saturated. This led to variant serial production and mass customization. Furthermore, the Third Industrial Revolution enabled globalization (Bauernhansl et al., 2014).

The Fourth Industrial Revolution started in 2011 with the introduction of the concept of "Industrie 4.0" on the Hannover Messe in Hannover, Germany (Drath, Horch, 2014). The term "Industrie 4.0" has evolved in the scope of the High-Tech Strategy of the German Federal Government (2014), which was responsible for the rapid spread of the term. "Industrie 4.0" is part of the "Zukunftsprojekt"[16] High-tech Strategy 2020 for Germany (2014). It founds "[o]n the basis of an advanced digitalization [sic!] within factories, the combination of [i]nternet technologies[,] and future-oriented technologies in the field of "smart" objects (machines and products) […]." (Lasi, Fettke, et al., 2014b, p. 239). Thus, a main aspect of Industry 4.0 are encompassing connected networks, communication, and IS in production and ICT (Bauernhansl et al., 2014; Kaufmann, 2015; Siepmann, Graef, 2016). The approach of smart factories is one vision of Industry 4.0 (Bauernhansl et al., 2014; Siepmann, Graef, 2016).

Figure 5 illustrates the development that is described by the four industrial revolutions. The aspects mentioned regarding the Fourth Industrial Revolution are explained in sections 2.2.2, 2.3, 2.4, and 2.5.

[16] Future project. Translated by the author.

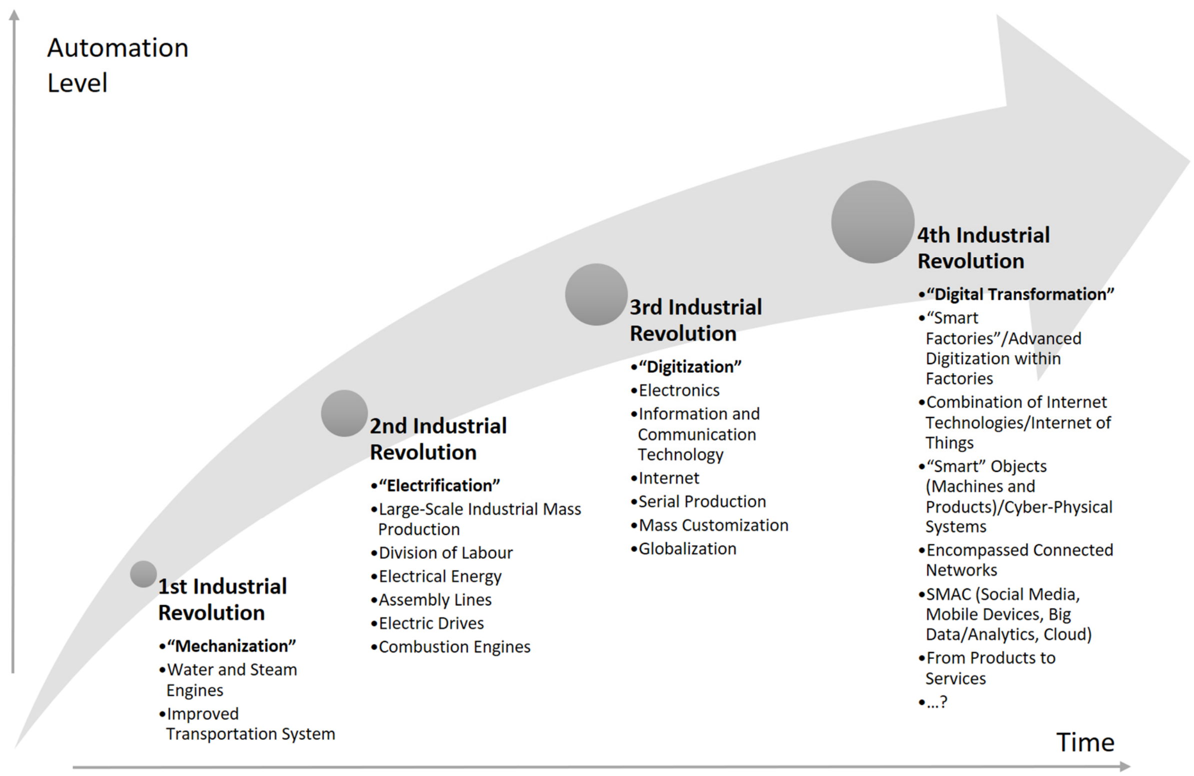

Figure 5: The four Industrial Revolutions

2.2.2 The Digital Transformation

The "Digital Transformation" – or "Digitization" describes the process a company is undergoing when changing from a "traditional" company to an Industry 4.0 company. As an example, Weiss (2017) describes possible changes in classic retail business, which may start with taking over ideas for logistics and robots in their warehouses – e.g., from Amazon – and end up with digitization in their stores, e.g., for digitally monitoring the inventory in the shelves.

According to Krcmar (2015d) the Digital Transformation is based on disruptive technological innovations, such as cloud computing. Krcmar (2015d) emphasizes, that this technological transformation affects various different areas. While "it is not possible to forecast market disruption [such as we see with the Digital Transformation] ex-ante, [the following] [c]riteria are a good first indicator [for a market disruption]" (Krcmar (2015d, min. 00:42 ff.) with regards to Christensen (1997)):

- "**Historically most valuated attributes**" (Krcmar, 2015d, min. 01:55 ff.) may "suddenly be less important" (Krcmar, 2015d, min. 01:55 ff.).
- "**Other quality criteria** [may] come into play" (Krcmar, 2015d, min. 02:01 ff.).
- "[…] **Costs** will be lower and […] possibly also the **margin**" (Krcmar, 2015d, min. 02:04 ff.).
- "Customers [may] see **more convenience and higher simplicity** in the new offerings" (Krcmar, 2015d, min. 02:09 ff.).

- "[T]he **interest of main customers** is low at first, partly because they already have solutions in place" (Krcmar, 2015d, min. 02:16 ff.).
- "[I]t is hard to develop […] new innovations [without **first customers**]" (Krcmar, 2015d, min. 02:23 ff.).
- "**[F]irst vendors** […] are very often not the same ones who have dominated a similar industry before" (Krcmar, 2015d, min. 02:28 ff.).
- There are "**changes in the value chain**" (Krcmar, 2015d, min. 02:35 ff.), …
- … "ultimately resulting in **market disruption**" (Krcmar (2015d, min. 02:35 ff.) with regards to Christensen (1997)).

Krcmar (2015b) describes the Digital Transformation with three questions:

- **What** is transformed? → Digital Transformation
- **Why** is it transformed? → Explanatory Model
- **How** does the transformation take place? → Leadership Behaviour

In this work we focus on what is needed to enable employees to work in Industry 4.0, thus we refer to the question of **what** is transformed in the Digital Transformation, as this affects what employees have to be prepared for.

Krcmar (2015b) summarizes his definition for the Digital Transformation as follows:

> *"Digital transformation [sic!] can be understood as an organizational change process where digital technologies (such as big data analytics, sensor networks, cloud services) are used to radically change:*
>
> 1. *How a company creates value*
> 2. *How it interacts with its customers and business partners*
> 3. *How it competes in established and emerging markets"*
>   (Krcmar, 2015b, min. 03:39 ff.)

Referring to this, Krcmar (2015c) names the main characteristics of the Digital Transformation:

- *"Demographic change*
- *Urbanization*
- *Serviceation [sic!]*
- *Predictability*
- *IT-Trends selection aka SMAC*
  - *Social Media*
  - *Mobility & Consumerization*
  - *Analytics / Big Data [sic!]*
  - *Cloud Computing*
  - *Internet of Things (IoT)*
  - *Cyber-Physical Service Systems (CPSS)*
  - *Platform-Based [sic!] Ecosystems"* (Krcmar, 2015c, min. 00:40 ff.),

whereas "SMAC", a term often used by consulting companies such as PricewaterhouseCoopers (PWC) (Baya, Gruman, Perker, 2012) and Gartner (Caldwel, 2013), includes Social, Mobile, Analytics, and Cloud[17].

As the Digital Transformation – which results in Industry 4.0 – is enabled and caused by the use and interplay of these characteristics, they can be seen as significant attributes of Industry 4.0. The substantial changes in some areas – such as the demographic change, urbanization, "serviceation" [sic!] (cp. Krcmar (2015c, min. 00:40 ff.)) – the emerging technologies in the area of sensors and computing, and the interplay of these characteristics indicate the enormous shifts a company has to undergo on its way to Industry 4.0. In section 2.3, the main technological characteristics are presented in detail.

2.2.3 Other Related Terms and Concepts

As the Fourth Industrial Revolution and the Digital Transformation take place in several regions of the world at the same time, several terms for these phenomena appear. E.g., Industry 4.0 – derived from the German term "Industrie 4.0" (Die neue Hightech-Strategie, 2014, p. 16; Sendler, 2013, p. 1 ff.) – is referred to as ""industrie du future" in France" (Prifti, Knigge, Kienegger, et al., 2017a, p. 50), the "Industrial Internet" (Grangel-González et al., 2016), the "Internet of Things" (IoT) or the "Internet of Everything", "Smart Factory" and "Factory of the Future" (Krcmar, 2015b, min. 02:09 ff.; Obermaier, 2016, p. 6; A. Roth, 2016, p. 6), the "Internet of Things and Services" (IoTS), "Next Generation Internet" (Krcmar, 2015b, min. 02:09 ff.), or "Smart Service World" (Kagermann et al., 2015a, p. 11 ff.; 2015b, p. 2 ff.; Krcmar, 2015b, min. 02:13 ff.). Companies such as Gartner add their own terms like "Nexus of Forces" (Caldwel, 2013). All these terms refer – more or less – to the same phenomenon.

2.2.4 Affected Industries and Businesses

Krcmar (2015b) emphasizes that the Digital Transformation is not only affecting recently emerging "digital" companies such as Netflix, Uber and Airbnb (Krcmar, 2015b, min. 01:18 ff.) – or the so-called "Silicon Valley stars" (Krcmar, 2015b, min. 04:19 ff.). While companies such as "[A]mazon, Google, and Apple" (Krcmar, 2015b, min. 01:18 ff.) have been drivers or parts of the Digital Transformation very early, companies categorized as rather "traditional", such as Allianz, BMW, Roche, or Kaeser Kompressoren, are significantly affected by the Digital Transformation as well (Krcmar, 2015b; Lasi, Fettke, et al., 2014b). An example is BMW with regards to the development of autonomous driving cars and its possible implications on the business model (selling/leasing/car-sharing etc.). Companies in almost every industry face the challenges of the Digital Transformation, changing their production processes, business and models as well as their sales and customer relationshiop management proceses. E.g., fortified by the Corona-crisis, among others, the education sector faced a strong need for digitization.

[17] For SMAC, social, mobile, cloud, and big data, cp. section 2.3.1; for Internet of Things (IoT), cp. section 2.3.1; for Cyber-Physical Service Systems (CPSS), cp. section 2.3.

2.3 Enabling and Characteristic Technologies of Industry 4.0

In this section, technologies that enable or are characteristic for Industry 4.0 are shortly described in order to gain a basic understanding as foundation for discussing the impact of Industry 4.0 on industry and society.

A **Cyber-Physical System (CPS)** enables not only automated production, but "(semi-)autonomous, self-organizing, and adaptive production processes" (Krcmar, 2015d, min. 10:19 ff.). It comprises "software, electronic hardware, sensors[,] and actuators as embedded systems [as well as] […] a human machine interface[.] and also [.] connection[s] to other systems" (Krcmar, 2015d, min. 10:29 ff.). "Systems emerge[,] whose [sic!] physical and digital representation cannot be differentiated in a reasonable way anymore." (Lasi, Fettke, et al., 2014b, p. 240).

A **Product-Service System (PSS)** includes the "[s]eamless integration of [cyber-physical] products and services to provide solutions for customer-specific problems (servitization [sic!])" (Krcmar, 2015d, min. 10:42 ff.).

Cyber-Physical Service Systems (CPSS) combine CPS and PSS. One of the main aspects of Industry 4.0 is the shift of the focus of economy from manufacturing to service offering. E.g., instead of selling cars, car sharing becomes a new business model. In the future, we may use car sharing which offers us autonomous driving cars – as an example of a CPSS.

The **Internet of Things (IoT)**, also called the **Internet of Things and Services (IoTS)** is a type of a CPS (Krcmar (2015d)). The "network of physical objects – "things" – which […] [is] embedded with all kinds of sensors, electronics, and also connectivity" (Krcmar, 2015d, min. 09:21 ff.) is called IoT. "Each "thing" is uniquely identifiable through its embedded computing infrastructure[,] and can interoperate with the existing [i]nternet infrastructure" (Krcmar, 2015d, min. 09:30 ff.). This may cause "serious security concerns" (Krcmar, 2015d, min. 09:42 ff.) as everything that is connected to the internet may be subject to cyberattacks. Krcmar (2015d) points out, that "the amount of things being interconnected will surpass the amount of people on earth in the future or already has done […]" (Krcmar, 2015d, min. 09:57 ff.). IoT "allows the ubiquity of user-oriented computing[.][;] [a]nd it will expand both in industrial and operational contexts" (Krcmar, 2015d, min. 09:46 ff.). The "[f]ocus of digital business products and processes" (Krcmar, 2015d, min. 10:13 ff.) will be on IoT, as there will be "many more things connected than [people]" (Krcmar, 2015d, min. 10:13 ff.).

"Manufacturing will completely be equipped with sensors, actors, and autonomous systems. By using "smart technology" related to holistically digitalized [sic!] models of products and factories (digital factory) and an application of various technologies of Ubiquitous Computing, so called **"Smart Factories"** develop[,] which are autonomously controlled" (Lasi, Fettke, et al. (2014b, p. 240) with regards to Lucke, Constantinescu, and Westkämper (2008)).

2.3.1 SMAC – Social, Mobile, Analytics, Cloud

With regards to Krcmar (2015c) and Gartner (Caldwel (2013)), "SMAC" is one of the technological drivers of the Digital Transformation – and therefore part of the technological foundation of Industry 4.0. "SMAC" comprises the components "Social", "Mobile", "Analytics", and "Cloud".

2.3.1.1 "Social"

Social media is present in private life, e.g., people make use of platforms such as Facebook, Instagram, Snapchat, TikTok, Twitter, or YouTube for staying connected to friends and family, to gain new contacts, and to share opinions and experiences, or to earn money as influencers – people who get paid by companies for producing content where they place the companies' products. Other social media platforms such as Xing and LinkedIn focus on connecting people on a professional level. Thus, "social" – or "social media" (Krcmar, 2015d, min. 04:59 ff.) includes the private, but also the professional use of by companies and organizations, e.g., for

- *"Marketing: increasing brand recognition through social media campaigns*
- *Product innovation: new product development through idea-sourcing [incl. crowdsourcing]*
- *Support: direct customer support substituted through community support"* (Krcmar, 2015d, min. 05:05 ff.).

This listing may be extended with the phenomenon of crowdfunding. Moreover, companies use social media as well to check the (private) profiles of applicants, customers, or employees. With regards to "social", Krcmar (2015d) emphasizes the "[p]ower of the masses: Social media radically changes the relationship between consumers and businesses" (Krcmar, 2015d, min. 05:24 ff.). With access to social platforms, everyone has the means to start an online business, e.g., as influencer. A job, which has not been known only some years ago.

2.3.1.2 "Mobile"

"Mobile" or "[m]obility and consumerization" (Krcmar, 2015d, min. 05:35 ff.) describe the fast increasing use of mobile and smart devices (e.g., smart phones, tablets) and wearable devices such as smart watches, smart glasses, smart fabrics, smart fashion, etc. Krcmar (2015d) determines, that "[o]ften, new technologies develop in the consumer space first and then get transferred into the business space" (Krcmar, 2015d, min. 05:55 ff.). He concludes, that "[u]ser experience design will be of critical importance also for business applications[…][,] [b]ecause the actual users, whether they are employees or consumers, are […] used to that type of interaction" (Krcmar, 2015d, min. 06:06 ff.).

2.3.1.3 "Analytics" and Big Data; Smart Data

"Analytics" or "Analytics and Big Data" (Krcmar, 2015d, min. 06:23 ff.) deals with the analysis of huge amounts of data that are generated by IoT and embedded devices (Krcmar, 2015d).

Social media is another important source where big data such is generated (e.g., product reviews). Analytics deals with structured data as well as unstructured data, which adds another level of complexity.

Big data enables managers to gather large amounts of data connected to their business processes. This data has to be transferred into knowledge to support their decision making and performance (McAfee, Brynjolfsson, Davenport, Patil, Barton, 2012). The large amounts of data available due to the use of new devices, such as sensors or sources such as social media, have to be prepared for analyses to be executed in an acceptable lapse of time. "Traditional" tools are often unable to cope with the sheer amount of data (Snijders, Matzat, Reips, 2012), thus, faster and more powerful tools such as in-memory DBs are needed. Moreover, employees have to learn how to analyse and interpret big data in a meaningful way. Russom (2011) describes and structures the challenges of big data by clustering it in three groups, the three "Vs", as illustrated in Figure 7. **"Volume"** describes the amount of the data: many terabytes (TB) instead of megabytes (MB) or gigabytes (GB) (1 TB = 1,000 GB = 1,000,000 MB), stored in many records, generated by lots of transactions or by sensors or extracted from social media applications – and saved in a lot of tables and files. **"Variety"** describes the different characteristics of the data: structured, semi-structured, or unstructured – or a mixture of all of these. **"Velocity"** describes the speed of the generation and changes in the data. They can be delivered via batch jobs, near-time, real-time, or streams for example. (Russom, 2011).

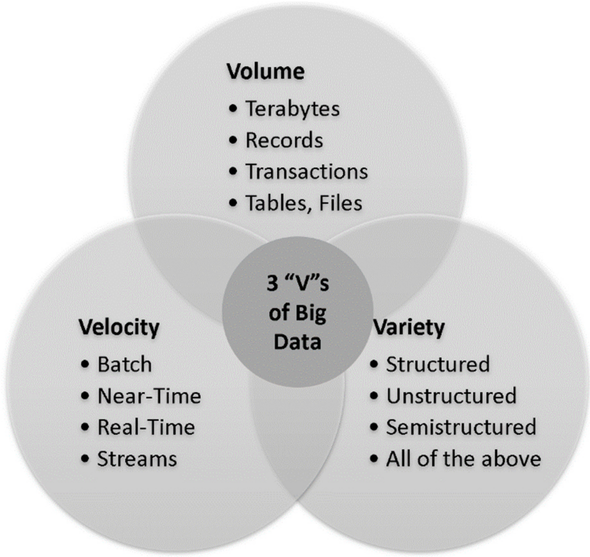

Figure 7: The three "V"s of Big Data (with regards to Russom (2011, p. 6))

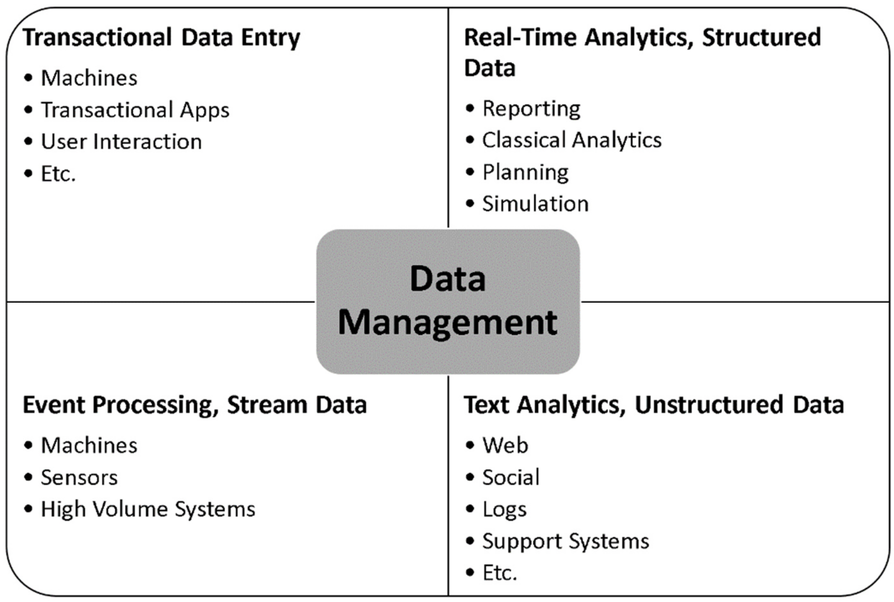

Figure 6: Challenges for Data Management Resulting from Diverse Applications (with regards to Plattner (2012, min. 00:49 ff))

Plattner (2012) describes challenges for data management resulting from diverse applications as shown in Figure 6. In accordance with this, Krcmar (2015d) gives examples for different kinds of input data, e.g., data extracted from software, such as ERP systems, sensor data, geodata, log files, texts, structured data, e.g., from databases , weather information, data from social media, etc.

As mentioned in section 2.1, Plattner (2012) claims that the differences between OLAP and OLTP are significantly smaller than expected and that the separation of OLAP and OLTP into different systems is not needed anymore (Plattner, 2012). Moreover, modern in-memory DBs have the power to host all business data combined and to compute the calculations needed on one server – which results in a big shift in the administration and use of EISs and BISs. In line with this, Krcmar (2015d) predicts, that "every application will become an analytic application, providing actionable insights into the consumer." (Krcmar, 2015d, min. 06:45 ff.). Alone the end of the paradigm of the separation of OLTP and OLAP changes the IS landscape significantly as future applications will combine both elements and therefore become more powerful and enable near-time and real-time reporting. Additionally, we can observe that EIS and BIS are increasingly offered as cloud versions (cp. section 2.3.1.4).

> The next step following big data is "Smart Data", the *"Generierung neuen Wissens aus mehr oder weniger strukturierten heterogenen Massen von Daten durch effektive Speicherung und fortgeschrittene Methoden des Datamining (z. B. Finden von unerwarteten[,] aber potentiell interessanten Korrelationen) […]. Eine Besonderheit kann darin gesehen werden, dass sich auch neue, noch unbekannte Fragestellungen überhaupt erst aus der Analyse ergeben sollen."*[18] (Smart Data, 2015, p. 4).

With the emerging smart data applications, new jobs arise in the IT-sector, e.g., the "Data Analyst". New degree programmes are following. However, it takes time for them to be developed. Nevertheless, smart data has to be integrated in advanced trainings inside companies as well (Anderl et al., 2015). For now, it is difficult to staff the emerging new jobs with qualified employees (Columbus, 2014) – especially in an IT job market with an already high demand for qualified employees in general (Anderl et al., 2015; IT-Trends 2020, 2015).

2.3.1.4 "Cloud"

Cloud computing means that private users and organizations do not maintain hardware and software themselves any longer, but use software provided online by cloud providers – via the "cloud" – instead. Users and providers are more separated than before, as the use of cloud services is location-independent (Krcmar, 2015d). Between them, there is a new "self-service [layer]" (Krcmar, 2015d, min. 07:24 ff.). A high level of standardization is needed for cloud offerings (Krcmar, 2015d). Services such as software provided over the cloud are switching "to a pay-per-use paradigm" (Krcmar, 2015d, min. 08:31 ff.), and therefore become commodities

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[18] The next step following big data is "Smart Data", the generation of new knowledge based on more or less structured, heterogeneous amounts of data by means of effective storage and advanced methods of data mining (e.g., discovery of unexpected, but potentially relevant correlations). It may be seen as specific characteristic that new, unknown questions arise only from the analysis itself. Translated by the author.

(Krcmar, 2015d) such as power or water. With these developments, the "IT fixed costs [and the corresponding risks] [shift] from consumer to provider [who are expected to deliver] high quality, highly available, [and] massively scalable IT resources" (Krcmar, 2015d, min. 07:42 ff.).

2.4 Consequences of Industry 4.0

The main characteristic of Industry 4.0 is not that it consists of a range of evolved and disruptive technologies. In fact, there are some of them, but the core of Industry 4.0 is the new combination, closer connection, and enhancement of already known technologies. This is in line with Lasi, Fettke, et al. (2014b), who state that "the term "Industry 4.0" describes different – primarily IT[-]driven – changes in manufacturing systems[...] [and that] [t]hese developments do not only have technological but furthermore versatile organizational implications" (Lasi, Fettke, et al., 2014b, p. 241). As mentioned in section 2.3, the focus of economy shifts from the manufacturing of products for the consumer to the offering services to him: "vom Kunden zum Konsumenten"[19] (Jung, 2016, p. 12), "vom Produkt zum Service"[20] (Jung, 2016, p. 13), and "von der Lizenz zur Innovation"[21] (from the perspective of an enterprise software company) (Jung, 2016, p. 13). Table 1 contains explanatory examples for these three statements.

Table 1: From Product to Services (with regards to Jung (2016, p. 12 f.))

Kunde ⇒ Konsument	Produkt ⇒ Service	Lizenz ⇒ Innovation
"Heute ist nicht mehr der direkte Geschäftspartner relevant, sondern der Endverbraucher. Dieser fordert auf sich zugeschnittene Produkte und Services. Dadurch werden zum Teil ganze Lieferketten übersprungen. Das Produkt wird zum individuellen Einzelstück und nach Verbraucherwunsch gefertigt […]. Hier stellt sich die Frage für Unternehmen: Wie können neue Geschäftsmodelle entstehen, die dieser Aufgabe gerecht werden?"[22] (Jung, 2016, p. 12).	*"In der Vergangenheit war der Produktlebenszyklus […] durch die Phasen Produktentwicklung, Angebot, Verkauf und Wartung bestimmt. Heute werden die Produkte nicht mehr erworben, sondern einfach durch den Service ersetzt, sie zu nutzen. Hier stellt sich die Frage für Unternehmen: Wie kann dieser neue bzw. komplexer gewordene Prozess in der Software abgebildet werden?"*[23] (Jung, 2016, p. 13).	*"Innovationen entstehen nicht einfach nur durch den Kauf und die bloße Installation einer Software. […] [Unternehmen] möchten heute Best Practices zum bestmöglichen Einsatz ihrer Software erhalten, damit es am Ende einen Mehrwert gibt. Idealerweise wird die Software [vom Anbieter] gemeinsam mit den Kunden*

[19] From customer to comsumer. Translated by the author.
[20] From product to service. Translated by the author.
[21] From license to innovation. Translated by the author.
[22] Today, the direct business partner is not relevant anymore, but the end customer. He demands for individually tailored products and services. Thus, whole delivery chains are missed out. The product becomes an individual item and is produced with regards to the consumer's demand. Companies are facing the question: How can new business models evolve which are able to satisfy these needs? Translated by the author.
[23] In the past, the product life cycle was determined by the phases product development, offering, sales, and maintenance. Today, products are not sold anymore, but simply replaced by the service to use them. Companies are

Kunde ⇒ Konsument	Produkt ⇒ Service	Lizenz ⇒ Innovation
		bedarfsgerecht entwickelt."[24] (Jung, 2016, p. 13).

Lasi, Fettke, et al. (2014b) comment this from the perspective of manufacturing:

> *"The vision of future production contains modular and efficient manufacturing systems and characterizes scenarios in which products control their own manufacturing process. This is supposed to realize the manufacturing of individual products in a batch size of one while maintaining the economic conditions of mass production." (Lasi, Fettke, et al., 2014b, p. 239).*

For the customer, such a customized product can be seen as "service" (Bundesverband Informationswirtschaft Telekommunikation und neue Medien e.V. (Bitkom) et al., 2016). Lasi, Fettke, et al. (2014b) point out that "[n]ew manufacturing systems should be designed to follow human needs instead of the reverse" (Lasi, Fettke, et al., 2014b, p. 240). Furthermore, they expect the "change from product- to service-orientation [to happen] even in traditional industries (Lasi, Fettke, et al., 2014b, p. 241). Krcmar (2015e) supports these theses as he uses the "value-in-use creation model" of Grönroos (2011, p. 291) to point out that production needs to be combined with the "customer's value creation" (Krcmar, 2015e, min. 02:21 ff.).

> Furthermore, he states: *"From a production perspective, […] this interaction between the goods and the customers is a joint production process. The consumer and the customer participate as a co-producer of resources and processes with the provider. […] And from a customer's perspective, it's [sic!] the interaction that actually delivers an added value […]."* (Krcmar, 2015e, min. 02:51 ff.).

Krcmar (2015e) transfers the shift from a product-centric to a customer-centric added value including service and support when pointing out that "[i]n the Industry 4.0 environment, we move from office-centered [sic!] processes where the coordination is done centrally to an understanding where the work pieces themselves coordinate production." (Krcmar, 2015e, min. 04:39 ff.). With regards to Scheer (2012), Lasi, Fettke, et al. (2014b) conclude, that "an appearance of new types of enterprises can be anticipated which adopt new specific roles within the manufacturing process [respective] the value-creation networks […]" (Lasi, Fettke, et al., 2014b, p. 241 f.).

Due to Lasi, Fettke, et al. (2014b), this development is supported by a "huge application-pull" (Lasi, Fettke, et al., 2014b, p. 239) on the one hand, which demands

- *"Short development periods […] [and] [h]igh innovation capability […]*

facing the question: How can this new, respectively more complex be implemented in software? Translated by the author.

[24] Innovations do not arise through just buying and installing a software. Companies today demand for best practices of the use of their software in order to generate value. Ideally, the software provider develops the software together with the customer to meet his demands. Translated by the author.

- *Individualization on demand: A change from a seller's into a buyer's market […] which means buyers can define the conditions for trade[;] […] increasing individualization of products […]*
- *Flexibility: […] higher flexibility in product development […]*
- *Decentralization: […] [for] faster decision-making procedures[;] […] organizational hierarchies need to be reduced*
- *Resource efficiency […]"* (Lasi, Fettke, et al., 2014b, p. 239).

On the other hand, Lasi, Fettke, et al. (2014b) describe an "exceptional technology-push in industrial practice" (Lasi, Fettke, et al., 2014b, p. 239), such as it was the case with "Web 2.0, [a]pps, [s]martphones, laptops, 3D-printers, etc." (Lasi, Fettke, et al., 2014b, p. 239 f.):

- *"Further increasing mechanization and automation […]*
- *Digitalization [sic!] and networking […]*
- *Miniaturization [of computing devices]"* (Lasi, Fettke, et al., 2014b, p. 240).

Not all these developments are new if considered in isolation. However, all together, they have "the potential to turn around the industrial practice comprehensively" (Lasi, Fettke, et al., 2014b, p. 240). These changes force companies to rethink and rebuild their business models. Krcmar (2015f) specifies five "archetypes of business model innovation" (Krcmar, 2015f, min. 02:22 ff.):

- *"Substituting [p]roducts and [s]ervices*
- *Rethinking [v]alue [p]ropositions*
- *Creating [n]ew [d]igital [b]usinesses*
- *Reconfiguring [v]alue [d]elivery [m]odels*
- *Reinventing [i]ndustries"* (Krcmar, 2015f, min. 02:22 ff.).

In the following, he identifies three *"overarching trends [in] [i]nternet-driven business model patterns[:]*

- *Integrate customers and users into the value chain, for example: User-designed, e-commerce, [o]pen [s]ource (content), and mass customization*
- *Service orientation: IT-based services allow companies to maintain and make use of customer relationships even after the sale, for example: Rent instead of buy, subscription, freemium, razors & blades, and add-on*
- *Core competence analytics: Precise collection and analysis of transaction and use data represent a key skill for product design, pricing, and sales structuring, for example: Subscription, flat rate, freemium, pay-per-use, and performance-based contracting"* (Krcmar, 2015f, min. 08:19 ff.).

Thus, Krcmar (2015f) concludes that three main trends that lead to Industry 4.0 are

- the concentration on and integration of customers and users in the value chain – "**customers first**",
- the focus on **service orientation**, and

- **big data analytics**, as the "[p]recise collection and analysis of transaction and use data represent a key skill for product design, pricing, and sales structuring […]" (Krcmar, 2015f, min. 09:09 ff.).

It is obvious that these trends will change the tasks and workplaces of employees – as they lead to the production different products and/or (corresponding) services then before. Communication and cooperation skills are crucial in Industry 4.0. Figure 8 illustrates those main aspects that determine business models in Industry 4.0.

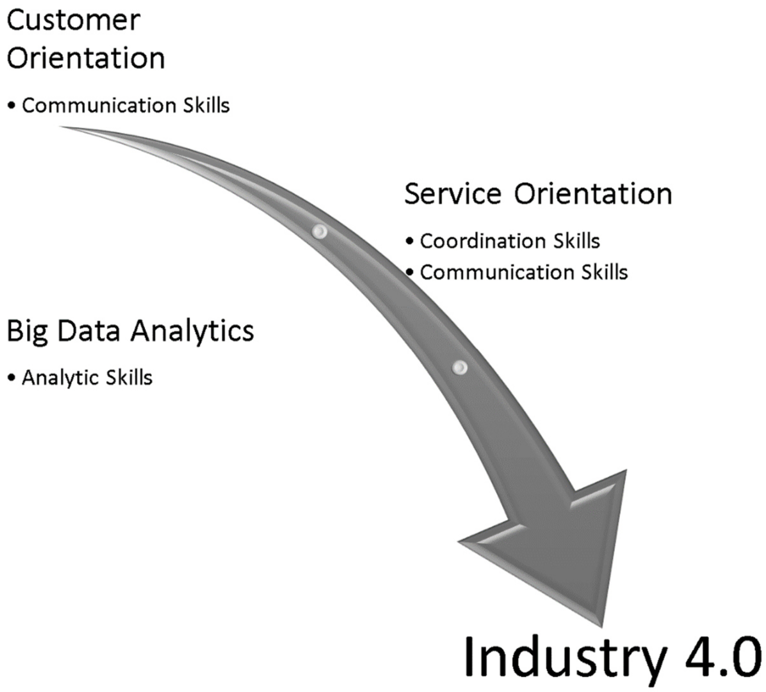

Figure 8: Characteristics of Industry 4.0 Business Models: Customer Orientation, Service Orientation, Big Data Analytics

2.5 Assignment of Industry 4.0-related Topics to IS/Business Informatics/Business and Information Systems Engineering

Lasi, Fettke, et al. (2014a, 2014b) point out, that with Industry 4.0, "new issues concerning the discipline of BISE [Business and Information Systems Engineering, the author] appear […] with regard to an appropriate degree of integration, automation[,] and decentralization of enterprise information systems" (Lasi, Fettke, et al., 2014b, p. 240). They assert, that "the term "Industry 4.0" describes different – primarily IT[-]driven – changes in manufacturing systems[,] […] [which] do not only have technological but furthermore versatile organizational implications" (Lasi, Fettke, et al., 2014b, p. 240). The authors give an overview of which topics of Industry 4.0 can be assigned to BISE – which includes fields such as IS, Business Informatics and parts of Economics, Computer Sciences, and Informatics:

- *"Integration of the physical basic system and the software system: New options by using real-time information via RFID* [radio-frequency identification; the author]*, sensors[,] etc. allow an advanced integration in various application systems.*
- *Integration with other branches and economic sectors […]. […] [e]specially commerce, logistics, but also financial services and other service providers play a central role.*
- *Integration with other industries and industry types: Although the discipline of BISE knows different types of plant [sic!], it remains unclear how the change between different types of plants can be supported adequately with […] IT.*
- *Integration in dynamic value-creation networks: Consideration of value-adding processes gains new aspects in the context of Industry 4.0 if production is carried out in dynamic networks over the whole product-lifecycle ([…]PSS). At this point[,] it is essential to develop adequate concepts which consider production under aspects of complementary and substituting network partners."*
  (Lasi, Fettke, et al. (2014b); cp. Fettke (2013)).

Furthermore, Lasi, Fettke, et al. (2014a, 2014b) bring out a list of application areas that newly evolve or are subject to big changes with Industry 4.0:

- *"Methods of modelling and reference models: New concepts within Industry 4.0 lead to a demand concerning advanced methods of modelling and specific reference models […] [(Fettke, Loos, 2004)]."* (Lasi, Fettke, et al., 2014b, p. 241).
- *"Innovative MES/ERP [Manufacturing Execution Systems/Enterprise Resource Planning, the author] approaches: […] innovative concepts for […] [MES and ERP systems] […] [(cp. Klöpper, Pater, Dangelmaier, 2012; M. T. Koch, Baars, Lasi, Kemper, 2010)]."* (Lasi, Fettke, et al., 2014b, p. 241).
- *"Business Intelligence [(BI), the author]: Based on the use of quantitative methods of […] [BI], initial concepts and models have already been developed and evaluated […] [(Gronau, 2012; Lasi, 2012)]."* (Lasi, Fettke, et al., 2014b, p. 241).
- *"Digital product memories: These systems allow for a collection of data records in all phases of product lifecycle, they additionally save them and distribute them for analysis. This covers data of individual production, assembling, distribution[,] etc. […] [(cp. Brandherm, Kröner, 2011)]."* (Lasi, Fettke, et al., 2014b, p. 241).
- *"Developing methodology: In Industry 4.0[,] innovative methodical approaches for planning and development of manufacturing systems are required. […] [(cp. Loskyll, 2013; Pohlmann, 2008)]."* (Lasi, Fettke, et al., 2014b, p. 241).
- *"Innovative platform architectures: […] [Wahlster (2014)] asserts that future manufacturing systems will be based on an innovative platform that bundles intelligent products, data, and services, and makes them consistently usable."*
  (Lasi, Fettke, et al., 2014b, p. 241).
- *"Data models and exchange formats: New manufacturing technologies such as Additive Manufacturing lead to new requirements in the field of data models and data exchange formats […] [(Lasi, Morar, Kemper, 2014)]. This concerns engineering-oriented application systems as well as application systems for business administration."*
  (Lasi, Fettke, et al., 2014b, p. 241).

According to these assumptions, employees have to be prepared for the technological changes as well as for the integration with other branches and industries. This higher interconnectedness affords employees to be open for the needs of other branches and industries and learn how to connect and interact with partners from other areas. This is another hint that flexibility and communication skills will play a major role in Industry 4.0.

2.6 Skills, Competencies, and Competency Models

In the following, a common understanding of the terms "skills" and "competencies" in the scope of this work is presented. This is a wide field that touches several disciplines and research areas, such as Education, Pedagogy, Psychology, Neurosciences, etc. It is not in the focus of this thesis to develop overall, comprehensive definitions of the terms "skill", "competency", "competency model" etc. Therefore, for each term a short general overview is given followed by a definition that will serve the needs in the scope of this work. We will neither focus on detailed aspects of skills and competencies, e.g., from a psychological or neuroscientific perspective, nor deep dive into the discussion of these terms as that would be out of the scope of this research project.

2.6.1 Skills and Competencies

The term "competency" is central in international discussions about the competitiveness of individuals, companies, and national economies (Gnahs, 2010; Hölscher, 2016). Not least because of the competency measurement studies Programme for International Student Assessment (PISA) (2017) and Programme for the International Assessment of Adult Competencies (PIAAC) (2017), conducted by the Organisation for Economic Co-operation and Development (OECD)[25] [sic!], the concept of competencies gain more public attention recently (Gnahs, 2010; Hartig, Klieme, 2006). (Hagn, 2017).

There exist several diverse definitions of competencies in daily life as well as in science (Hartig, Klieme, 2006). E.g., in different disciplines such as Education, Psychology, Human Resources, Organizational Managements, or IS, discussing the meaning of the term is still ongoing (Delamare Le Deist, Winterton, 2005). Some of the definitions are contradicting (Gnahs, 2010). This results from the different origins of the term (Vonken (2005), Jude, Hartig, and Klieme (2008) with regards to Chomsky and Lange (1973) and H. Roth (1971)). While in German-speaking areas, Chomsky and Lange (1973) are seen as the ones who introduced the concepts of competencies to Education sciences, in English-speaking areas it is usually referred to McClelland (1973) (Lee, 2010; Vonken, 2005). There are still general differences in the understanding of the concept of competencies between German- and English-speaking areas (Erpenbeck, von Rosenstiel, Grote, 2013). Furthermore, there are even different definitions in both of them, German- and English-speaking areas (Shippmann et al., 2000). (Hagn, 2017).

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[25] Organisation for Economic Co-operation and Development (OECD) [sic!]: The OECD's mission "is to promote policies that will improve the economic and social well-being of people around the world" (2018). http://www.oecd.org/. Accessed on July 30th, 2018.

Chomsky and Lange (1973) describe a competency as the potential – i.e., the cognitive structures – that potentially allows people to do something. While the potential itself cannot be measured, the use of it is measureable (Vonken (2005) with regards to Chomsky and Lange (1973)). Thus, they differentiate between competency and performance – a differentiation that can be used in common (Gnahs, 2010; Kaufhold, 2006). H. Roth (1971) defines a wider definition of the term of competencies. He includes feelings and motivation and differentiates between self-competency, professional competencies, and social competencies. (Jude et al. (2008) with regards to H. Roth (1971)). (Hagn, 2017).

Hartig and Klieme (2006) refer to Weinert (1999) when they gives an overview of different definitions of competencies:

> „*1. Kompetenzen als generelle kognitive Leistungsdispositionen, die Personen befähigen, sehr unterschiedliche Aufgaben zu bewältigen,*
> *2. Kompetenzen als kontextspezifische kognitive Leistungsdispositionen, die sich funktional auf bestimmte Klassen von Situationen und Anforderungen beziehen. Diese spezifischen Leistungsdispositionen lassen sich auch als Kenntnisse, Fertigkeiten oder Routinen charakterisieren,*
> *3. Kompetenzen im Sinne der für die Bewältigung von anspruchsvollen Aufgaben nötigen motivationalen Orientierungen,*
> *4. Handlungskompetenz als eine Integration der drei erstgenannten Konzepte, bezogen auf die Anforderungen eines spezifischen Handlungsfeldes wie z. B. eines Berufes,*
> *5. Metakompetenzen als das Wissen, die Strategien oder die Motivation, welche sowohl den Erwerb als auch die Anwendung spezifischer Kompetenzen erleichtern,*
> *6. Schlüsselkompetenzen als Kompetenzen im unter 2. genannten funktionalen Sinn, die aber für einen relativ breiten Bereich von Situationen und Anforderungen relevant sind. Hierzu gehören z. B. muttersprachliche oder mathematische Kenntnisse.“*
> (Hartig, Klieme, 2006, p. 128 f.)[26].

Weinert (1999) proposed to use the second definition. Thus, he defines competencies as only determined cognitive, context-related, and functional (Hartig and Klieme (2006) and Klieme (2004) with regards to Weinert (1999)). Later, Weinert (2001) includes motivational, volitional, and social elements. This definition is seen as reference today (Klieme, 2004). Weinert (2001) now defines competencies as "die bei Individuen verfügbaren oder durch sie erlernbaren kognitiven Fähigkeiten und Fertigkeiten, um bestimmte Probleme zu lösen, sowie die damit verbundenen motivationalen, volitionalen […] und sozialen Bereitschaften und Fähigkeiten, um

[26] 1. Competencies as general cognitive abilities that enable people to cope with very different tasks,
2. Competencies as context specific abilities that refer functionally to specific classes of situations and requirements. These specific abilities can be characterized as knowledge, skills, or routines,
3. Competencies as motivational orientations that are needed to execute demanding tasks,
4. Competencies as integration of the first three concepts, referring to a specific sphere of action, e.g., a job,
5. Meta competencies as knowledge, strategies or the motivation that facilitate both, the acquirement as well as the application of specific competencies,
6. Key competencies as functional competencies as named under 2., but relevant for a broad range of situations and requirements. E.g., native language or mathematical skills. Translated by the author.

die Problemlösungen in variablen Situationen erfolgreich […] nutzen zu können" (Weinert, 2001, p. 27 f.)[27]. "Ability" in this context means skills together with knowledge (Gnahs, 2010). The German term "Handlungskompetenz" refers to this and often includes abilities such as problem-solving, critical thinking, self-confidence, social competencies, domain-specific and cross-domain knowledge (Weinert, 2001). The different definitions of the term competency as well as different ways of clustering them make it difficult to measure the success of single qualification actions (Hartig, 2008). (Hagn, 2017).

McClelland (1973) and Klemp Jr (1980) give further definitions for the term competencies. Both emphasize that competencies are personal traits, habits, or characteristics which lead to "effective and/or superior performance on the job" (Klemp Jr, 1980, p. 21). Bartram, Robertson, and Callinan (2002) are close to the previous definitions as they define competencies as "sets of behaviours that are instrumental in the delivery of desired results or outcomes" (Bartram et al., 2002, p. 7). This implies, e.g., that a specific programming language is only a part of a competency – a "skill". Competencies are more than that, e.g., the competency to build a software comprises much more than the ability to use a specific programming language – which may comprise several skills. Thus, beyond comprising skills, competencies include the knowledge and abilities of how to make use of skills as well as the corresponding mind-set and behaviour needed to fulfil a task. Delamare Le Deist and Winterton (2005) identify three approaches for defining competencies: the functional approach, the holistic/multi-dimensional approach, and the behavioural approach (Prifti, Knigge, Kienegger, et al., 2017a). An overview of these approaches is given in Table 2.

Table 2: Three Approaches for Defining Competencies (with regards to Prifti, Knigge, Kienegger, et al. (2017a))

Functional	Holistic/Multi-Dimensional	Behavioural
Competencies = **skills** needed to fulfil a task (E. Frank, 1991; Miller, 1991)	Competencies = collection of competencies required by **individuals** + competencies required by an **organization** (Straka, 2004)	Competencies **include "attributes which go beyond the cognitive ability**, like self-awareness, self-regulation[,] and social skills" (Prifti, Knigge, Kienegger, et al. (2017a, p. 48) with regards to McClelland (1973) and Boyatzis (1982))

The goal of this thesis is to develop a competency model for employees in Industry 4.0 and a prototype curriculum. As the competency model should be comprehensive for the topic of Industry 4.0, a behavioural model is developed. This includes "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" (Prifti, Knigge, Kienegger, et al. (2017a, p. 48) with regards to Klendauer, Berkovich, Gelvin, Leimeister, and Krcmar (2012)). As it covers

[27] Weinert (2001) now defines competencies as the competencies and skills for solving specific problems available or learnable by individuals as well as the connected motivational, volitional and social willingness and abilities to be able to use the problem solving successfully in variable situations. Translated by the author.

many aspects of the definitions of competencies given before, we stick to the definition of competencies given by the OECD-project "Defining and Selecting Key Competencies":

> *"Eine Kompetenz ist die Fähigkeit zur erfolgreichen Bewältigung komplexer Anforderungen in spezifischen Situationen. Kompetentes Handeln schließt den Einsatz von Wissen, von kognitiven und praktischen Fähigkeiten genauso ein wie soziale und Verhaltenskomponenten (Handlungen, Gefühle, Werte und Motivationen)".* (Gnahs, 2010, p. 21)[28].

In contrast to competencies, qualification describes "definierte Bündel von Wissensbeständen und Fähigkeiten, die in organisierten […] Bildungsprozessen vermittelt werden". (Gnahs, 2010, p. 21)[29]. The curriculum developed in the context of this thesis is tailored to convey specific behavioural competencies, such as digital literacies (Eshet-Alkalai, 2004), or smart data analytics, which can be adapted to different contexts and situations – or target groups. Besides delivering competencies for Industry 4.0, it is also suited to build up specific skills (or functional competencies), as it comprises practical exercises and case studies as well. While these skills, of course, are limited to the specific implementation of technologies in the prototype curriculum for Industry 4.0, the competencies taught are overall and transferable to other settings.

2.6.2 Job Profiles and Competency Profiles

A job description contains the information, which tasks a person needs to fulfil, and what specific qualification is required for the specific job described. This qualification contains a set of competencies. As not each job in a company is unique and requires unique qualification, typical jobs are described with job profiles – the sets of qualifications needed can be referred to as competency profiles.

2.6.3 Competency Models – the SHL Universal Competency Framework

Competency models describe collections of competencies that are required to fulfil specific tasks in a certain context (Campion et al., 2011; Stevens, 2013). A view into scientific literature and literature from practice reveals the broad spectrum of possibilities for using competency models. There exist competency models for specific skills such as eating (Satter, 2007), for different domains from health (Brady, Smith, 2011) to military (Oden, Ross, Rivera, Phillips, 2011), and for different jobs, from private club manager (Koenigsfeld, Kim, Cha, Perdue, Cichy, 2012) to firefighters (Li, Tiana, Gao, 2014). Different competency models rely on different concepts of competencies (Erpenbeck et al., 2013). Today, almost every large and lots of medium-sized companies have their own competency models (Erpenbeck et al., 2013). This is partly due to the fact that they use them for different purposes, e.g. when recruiting new employees, developing qualification programs, evaluating and promoting employees, or for compensation (Campion et al., 2011). Similar to competencies, competency models suffer from a

[28] A competency is the ability to cope successfully with complex demands in specific situations. Competent action includes the use of knowledge, of cognitive and practical abilities, as well as social and behavioural components (actions, feelings, values, and motivation). Translated by the author.

[29] In contrast to competencies, qualification describes defined packages of knowledge and abilities, which are taught in organized educational processes. Translated by the author.

lack of accuracy in science (Shippmann et al., 2000; Stevens, 2013). However, there are practice-proven competency models (Campion et al., 2011). (Hagn, 2017).

> *"[…] [The Handbuch Kompetenzmessung (2007)] offer[s] a [competency] model […] [that separates] the competencies into four categories: personal, social/interpersonal, action-related[,] and domain related […]. […] [Nippa and Egeling (2009)] use another classification by separating competencies in meta, domain, method[,] and social competencies. Other authors offer competency models for leadership and management […] [(Bassellier, Reich, Benbasat, 2001; Boyatzis, 1982; Miller, 1991)]. There are also competency models for certain tasks or job profiles […] [(Klendauer et al., 2012; Nippa, Egeling, 2009)]."* (Prifti, Knigge, Kienegger, et al., 2017a, p. 49).

The methodology and implementation of a competency model should be chosen depending on the goal of the competency model to be built (Stevens, 2013). However, in general, competency models tend to have similar structures (Sauter, Staudt, 2016). Typically, they can be described with two dimensions (Xiong, Tian, Yuan, Xu, Yu, 2011). The first one is the kind of competencies they describe. They can be relevant for everyone in an organization, regardless of job, or position – or they can be specific for certain jobs or departments (Campion et al., 2011; Xiong et al., 2011). The second dimension is the application area of the model. It may be a single-job competency model, or a general one for all jobs – or something in between (Sauter, Staudt, 2016; Xiong et al., 2011). The later version may comprise both, general as well as specific competencies (Campion et al., 2011). In addition, a third dimension can be specified: competency models may be arranged hierarchically, e.g., with categories and sub-categories (Campion et al., 2011). The competency model for employees in Industry 4.0 that is developed in the scope of this work is Industry 4.0-, but not industrial-sector- or job-specific. Therefore, it will contain both, general as well as Industry 4.0-specific competencies.

As there already exists several competency models in practice, we renounce to develop another competency model from scratch in the scope of this work. Instead of that, we build on existing research results. Since our competency model should be comprehensive for the topic of Industry 4.0, we decided to develop a behavioural model. As the definition of competencies proposed by Bartram et al. (2002) is close to our understanding of competencies, it is an obvious approach to examine if Bartram et al. (2002) made use of competency models in their work as well – and if so, if their approach is applicable for our work.Bartram (2005), Bartram (2011) and CEB Inc.[30], introduced the SHL[31] Universal Competency Framework (UCF). "CEB Inc. […] offers the SHL […] [.]UCF[.] as a generic foundation for building competency models" (Prifti, Knigge, Kienegger, et al., 2017a, p. 49). As this behavioural-based framework fits our needs, and as it is used both in research and practice, we decided to build the first version of our competency model for employees in Industry 4.0 on this (Prifti, Knigge, Kienegger, et al., 2017a). With this approach, we build on an accepted framework on the one hand. On the other hand, this approach allows the comparison of our competency model with others that use the

[30] CEB Inc. was a "global […] technology company providing services to business worldwide" (Prifti, Knigge, Kienegger, et al., 2017a). Please cp. https://www.cebglobal.com/. Accessed on May 28th, 2018. Today, it belongs to Gartner. Please cp. https://www.gartner.com/en. Accessed on November 8th, 2020.

[31] SHL is a technology company. Please cp. https://www.shl.com/. Accessed on November 8th, 2020.

SHL UCF as basis. The SHL UCF comprises three hierarchical levels. The first level is called "SHL's "Great Eight" Competencies" (Bartram, 2005, p. 1187; 2011, p. 7). These "Great Eight" are presented in Table 3.

Table 3: SHL UCF: The "Great Eight" Competencies (with regards to Bartram (2005, p. 1187) and Bartram (2011, p. 7))

SHL UCF: The "Great Eight" Competencies	
Leading and Deciding	Takes control and exercises leadership. Initiates action, gives direction, and takes responsibility.
Supporting and Co-Operating	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 and 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 learns new technology. Communicates well in writing.
Creating and Conceptualising	Open 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. Focusses 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 with setbacks.
Enterprising and Performing	Focusses 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.

On the second hierarchical level, Bartram (2005) identified 20 "Competency Dimensions" that he allocated to the "Great Eight". He then clustered "Competency Components" on the third hierarchical level into these "Competency Dimension". We decided to use the "Great Eight" as first level and the "Competency Dimensions" as second level for structuring our competency model for Industry 4.0. Therefore, these "Competency Dimensions" are presented in Table 4.

Table 4: "Great Eight" and "Competency Dimensions" (with regards to Bartram (2005, p. 1202 f.))

"Great Eight"	"Competency Dimensions"
Leading and Deciding	− Deciding and Initiating Action − Leading and Supervising
Supporting and Co-Operating	− Working with People − Adhering to Principles and Values

"Great Eight"	"Competency Dimensions"
Interacting and Presenting	– Relating and Networking – Persuading and Influencing – Presenting and Communicating Information
Analyzing and Interpreting	– Writing and Reporting – Applying Expertise and Technology – Analyzing
Creating and Conceptualising	– Learning and Researching – Creating and Innovating – Formulating Strategies and Concepts
Organizing and Executing	– Planning and Organizing – Delivering Results and Meeting Customer Expectations – Following Instructions and Procedures
Adapting and Coping	– Adapting and Responding to Change – Coping with Pressure and Setbacks
Enterprising and Performing	– Achieving Personal Work Goals and Objectives – Entrepreneurial and Commercial Thinking

Next, we allocated our competency requirements for employees in Industry 4.0 on the third level – the "behaviour level" – to the "Competency Dimensions" to build our new competency model. The results are presented in detail in section 4.1.3 as well as by Prifti, Knigge, Kienegger, et al. (2017a) and Prifti, Knigge, Kienegger, et al. (2017b).

2.7 Learning

In the scope of this thesis, it is neither possible nor needed to give a complete overview of the whole body of research in the wide field of learning. Instead, the author concentrates on the aspects that mostly serve in supporting the purposes and needs of this work.

Kolb (1984) defines "Learning […] [as] the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). He describes different levels of sophistication with regards to the age and previous knowledge of a person (Kolb, 1984). Following Dewey (1938), Kolb (1984) states that "[k]nowledge is the result of the transaction between social knowledge and personal knowledge" (Kolb, 1984, p. 36), where the first is the "civilized objective accumulation of previous human cultural experience, whereas the latter is the accumulation of the individual person's subjective life experiences. Knowledge results from the transaction between these objective and subjective experiences in a process called learning" (Kolb, 1984, p. 36 f.).

2.7.1 Learning Approaches – Experiential Learning

Learning comprises many different aspects. These belong to different fields of research such as Education, Didactics, Pedagogy, Psychology, and Neurosciences. As it is hardly possible to consider all aspects that are influencing the learning process and its outcomes at the same time, different approaches and theories with focusses on different aspects evolved over time. Table 5 presents a brief comparison of cognitive, behavioural, and experiential learning approaches.

Table 5: Comparison of cognitive, behavioural, and experiential learning approaches

Rational, Cognitive Learning	Behavioural Learning	Experiential Learning
Focus on "acquisition, manipulation, and recall of abstract symbols" (Kolb, 1984, p. 20)	"[Denial] of any role for consciousness and subjective experience in the learning process" (Kolb, 1984, p. 20)	" [C]entral role [of] experience […] in the learning process" (Kolb, 1984, p. 20)

In the following we stick to the approach of experiential learning as proposed by Kolb (1984), as we believe that learning happens best through experiences and cannot be seen separated from the environment where it happens. This experiential learning approach bases on the works of Dewey (1938), Lewin (1964) and Piaget (Kolb, 1984, p. 20). Kolb (1984) first compares their approaches and then distinguishes experiential learning from behavioural and cognitive learning approaches. He claims that experiential learning is not a third learning approach, but rather offers "a holistic integrative perspective on learning that combines experience, perception, cognition, and behavior [sic!]". (Kolb, 1984, p. 20 f.). The experiential learning approach "emphasize[s] the central role that experience plays in the learning process" (Kolb, 1984, p. 20)

> Dewey (1938) stated that *"[a]n experience is always what it is because of a transaction taking place between an individual and what, at the time, constitutes his environment, whether the latter consists of persons with whom he is talking about some topic or event, the subject talked about being also a part of the situation; the book he is reading (in which his environing conditions at the time may be England or ancient Greece or an imaginary region); or the materials of an experiment he is performing. The environment, in other words, is whatever conditions interact with personal needs, desires, purposes, and capacities to create the experience which is had. Even when a person builds a castle in the air he is interacting with the objects which he constructs in fancy."* (Dewey, 1938, p. 42 f.; cited from Kolb, 1984, p. 35).

Concerning the concept of experiential learning, we can derive several aspects from this statement that influence learning – and therefore should be considered while designing, executing, or evaluating learning situations:

- Individual – the learner:
  - Personal needs
  - Personal desires
  - Personal purposes
  - Personal capacities
  - Motivation – extrinsic or intrinsic – you want to learn or you have to learn something?
- Instructor: Trainer or teacher
- Environment:
  - Persons (e.g., other learners, the one who pays for the training)
  - Place – where the learning happens

- Subject: Topic, event, or subject
- Materials: Book, or materials of an experiment – the training materials.

Kolb (1984) states, that “personal characteristics, environmental influences, and behaviour [sic!] all operate in reciprocal determination, each factor influencing the others in an interlocking fashion” (Kolb, 1984, p. 36). Therefore, it is important to have a holistic view on the learning process for being able to consider all influencing factors of this complex process – which is challenging due to the given complexity and manifoldness.

2.7.2 Stakeholders of Learning

There are several (groups of) people, who have – partly conflictive – intentions in a learning process. First, there are the learners, the ones who want to – or need to – gain new or deepen their already existing knowledge. It makes a difference, if learners have an intrinsic motivation to learn something – or if someone else has an interest that they learn specific things and the power to make them do so (cp. section 2.7.3). There is the training provider, who wants to deliver a good training in order to keep or gain customers for future trainings and who has to prepare the training and the materials with limited resources. Next, there is management who allows or wants its employees to take part in training and takes the expenditures including training costs and off-times. Finally, yet importantly, there are the trainers who conduct the training. All these different groups of people have their own interests regarding the training, e.g., learning, earning money, which are (partly) contrarious.

2.7.3 Motivation for Learning

For the learning process, it makes a big difference if the learner wants to learn something (intrinsic motivation) or if someone else wants him to gain new or deepen already existing knowledge (extrinsic motivation). “Someone else” may be parents who want their children to learn. It may be a company that trains its employees to prepare them to execute tasks needed to fulfil the company’s goals. Children or employees may be interested in the topics and eager to learn about it – which means that there is intrinsic motivation as well. However, it is also possible, that they are not interested in a specific topic – but have to learn it, e.g., for the sake of the company’s needs. Without any or with hardly any intrinsic motivation, it is much harder to learn. Moreover, there may even be a certain degree of resistance against learning.

2.7.4 Learning Environment

The learning environment has its part in the success of a training event as well. The learner should be able to focus on the training without being disturbed by bad light, noises, smells etc. In case of a learning that takes place over several days, it is important that the learners have access to drinks, food and restrooms in good quality during the breaks. For some topics, laboratories or computer-pools may be needed. The equipment should be tested before so that the teaching and learning process is not disturbed by any non-functional equipment.

2.7.5 Learning Materials

The learning materials, e.g., slide decks, exercises, or case studies, should support the trainer in teaching and help the learner to get access to the content, to understand it, and to become able to apply the new knowledge. Therefore, they should be focussed – not to detailed, but detailed enough, easy to read and understandable for the audience at hand. E.g., an apprentice needs different information presented in a different kind of speech than someone who already has been working in a job for several years. Learning materials with too much badly written texts may quickly frustrate the learners.

2.7.6 Learning and Teaching Methods

There exists an innumerable amount of different learning, teaching, and training methods, from reading books over classroom teaching, online learning, videos, and flipped classrooms. Not every teaching method is suited for every purpose. E.g., when learning a programming language, it makes sense to have a system available for practical hands-on exercises. Teaching methods should help to keep the learner to the topic and provide it in an activating way to him. E.g., classroom teaching may get boring quickly. It can be mixed with interactive elements, such as online votes, group work, projects, or workshops. The "right" teaching method is dependent on many factors, such as the learner, the trainer, the topic, the environment, the resources, etc.

We can conclude that the outcome of learning depends on various aspects which interact with each other. Thus, trainings and learning are complex processes.

2.8 Curriculum/Curriculum Development

There exist several definitions of the concept of a "curriculum". These include different concepts from a single syllabus or the content for a one-semester lecture to a whole course of study in a university, or a complete graduate school programme. In the context of this thesis, we stick to Tyler (1975), who describes a curriculum as a holistic construct including knowledge creation as well as a set of learning or education experiences. Thus, we understand a curriculum as an artefact comprising teaching materials for a specific, well-defined topic and an expected learning outcome. A curriculum in this sense comprises a set of materials such as slide decks, use cases, videos, hands-on exercises, case studies, data sets, etc. Moreover, a curriculum may contain documentation for the lecturer, such as teaching notes, which explain how to set up a class and how to use the materials provided, or example solutions for exercises.

Curriculum development has been the focus of research for many decades (e.g., Compeau et al. (1995) and Gupta, Bostrom, and Huber (2010)). Authors such as Tyler (1975), Biggs (2003), Biggs and Tang (2007), and Schaper, Reis, Wildt, Horvath, and Bender (2012) suggested methods for developing and delivering content to students by following different approaches based on different theories. E.g., Biggs (2003) based his method on the concept of constructivism. He suggests that students should learn by engaging actively in the process of learning and by gaining practical experiences with the material. Similar to this, Kolb (1984) votes for experiential learning by emphasizing that learning occurs through experience (cp. section 2.7.1). We agree that interactivity in class has shown to be meaningful and well suited to motivate students. The main goal of education is to create knowledge (Anderson et al., 2001). Tyler (1975) describes a curriculum as a holistic construct that includes knowledge creation as well as a set of learning or education experiences. Schaper et al. (2012) propose to develop a university curriculum following six phases. Following this approach in our curriculum development project, we derived six phases necessary for our development process. These six phases adjusted to our needs are shown in Table 6.

Table 6: Content-Related and Conceptual Steps in Competency-Oriented Curriculum Development (with regards to Schaper et al. (2012, p. 38 f.))

Phase	Content-Related and Conceptual Steps
1	– Define qualification goals and the competencies that should be achieved through overall guidelines – Analyse requirements and needs – Derive and frame competency profiles
2	– Define learning outcomes and qualification goals using taxonomical criteria and systematics
3	– Define curriculum modules/learning units of the curriculum with regards to the learning outcome – Implement curriculum modules/learning units – Harmonization/evaluation of the curriculum modules/learning units
4	– Implement teaching guidelines – Define workload per curriculum module/learning unit
5	– Develop accompanying measures
6	– Plan and develop evaluation and quality assurance (QA) mechanisms – Conduct a pilot session with (parts of) the curriculum modules/learning units – Revise and optimize

The specific implementation of the curriculum concerning the phases described in Table 6 is documented in section 5.1.3.

2.9 Learning and Training Evaluation

For the evaluation of training, different approaches were introduced over time in different fields connected to the subjects of qualification, learning and training. Prominent and widely accepted example are the four levels approach presented by Kirkpatrick (1975) and the measurement of the return on investment (ROI) of training proposed by Griffin (2014). While giving an overview of different training evaluation methods, Singh (2013) points out, that none of the proposed evaluation models alone "can cater to all requirements of training evaluation" (Singh, 2013, p. 27). Thus, it is still a challenge to evaluate trainings and curricula in IS (Pineda, 2010). In the scope of our curriculum development project, our goal is to present evaluation mechanisms that can be used by a wide range of the prospective users of the curriculum. As exams at institutions of (higher) education have to be in line with the individual regulations of those institutions and their departments, our goal is not to provide exams that can be used by the customers, but mechanisms to evaluate the learning outcomes during the lectures.

3 Research Design

> Hevner et al. (2004) point out, that there are *"[t]wo paradigms [that] characterize research in […] [IS]: behavioral [sic!] (or natural) sciences and design science. Whereas the behavioural [sic!] science paradigm seeks to discover and verify laws or principles that explain or predict human or social behavior [sic!], the design science paradigm seeks to extend the boundaries of human and social capabilities by creating new and innovative artifacts [sic!]."* (Hevner et al., 2004, Abstract).

While "IT [research] that uses a behavioral [sic!] (natural) science paradigm is fundamentally reactive" (Hevner et al., 2004, p. 1), "IT [research] that uses a [D]esign [S]cience paradigm is fundamentally proactive" (Hevner et al., 2004, p. 1). The goal of Design Science is "to create innovative artifacts [sic!] that extend human and social capabilities and aim to achieve desired outcomes. These artifacts [sic!] often define the object of study in behavioral [sic!] IT research." (Hevner et al., 2004, p. 1).

In the scope of this thesis, a competency model for employees in Industry 4.0 and a curriculum for Industry 4.0 are developed as central artefacts. Therefore, the overall structure of this thesis is derived from the Design Science approach as proposed by Hevner et al. (2004).

3.1 Design Science

The main goals of this thesis are to provide a competency model for employees in the emerging field of Industry 4.0, and – building on this – a prototype curriculum for Industry 4.0 comprising teaching and training materials. As Hevner et al. (2004) state that Design Science searches to solve problems with creative innovations, their approach is taken as framework for this thesis. Two "new and innovative artifacts [sic!]" (Hevner et al., 2004, Abstract) are created in the scope of this work: the competency model and the prototype curriculum. These can be used "to extend the boundaries of human and organizational capabilities" (Hevner et al., 2004, Abstract). To create such artefacts in the IS profession, Hevner et al. (2004) propose a "framework for understanding, executing, and evaluating [D]esign [S]cience research in the Information Systems (IS) field and […] guidelines for its conduct and evaluation" (Hevner et al., 2004, Abstract). In this section, it is explained how the Design Science framework and guidelines proposed by Hevner et al. (2004) are applied in this research project. An overview of the guidelines is provided in Table 8 in section 3.1.2, an overview of the frameworks tailored for the development of the two artefacts is given in Figure 9 in section 3.1.2.1 and Figure 10 in section 3.1.2.2.

As the prototype curriculum for Industry 4.0 builds on the competency model for employees in Industry 4.0, the competency model is created in a first iteration applying the Design Science framework and guidelines as proposed by Hevner et al. (2004). In a second iteration, the prototype curriculum is implemented with the competency model for employees in Industry 4.0 serving as part of the knowledge base (cp. section 3.1.2).

3.1.1 Design Science in Information Systems

Simon (1996) stated, that Design Science originates in engineering and the sciences of the artificial. With regards to Glass (1999), Bringing Design to Software (1996), and Winograd (1997), Hevner et al. (2004) state that "Design [S]cience plays a central role in the development and management of [I]nformation [T]echnologies and [S]ystems" (Hevner et al., 2004, p. 1). Hevner et al. (2004) conclude, that Design Science "reaches to the very core of what [I]nformation [S]ystems practitioners and researchers do – create, apply, evaluate, and improve […] [.]IT[.] artifacts [sic!]" (Hevner et al., 2004, p. 1). They emphasize that "the construction of new, innovative artifacts [sic!] can have far reaching impacts on organizations" (Hevner et al., 2004, p. 2). Hevner et al. (2004) cite Fuller and Kuromiya (1992) when saying that "the goal of [D]esign [S]ience [is] [.] to solve problems by introducing into the environment new artifacts [sic!], the availability of which will induce their spontaneous employment by humans and thus, coincidently, cause humans to abandon their previous problem-producing behaviors [sic!] and devices" (Hevner et al., 2004, p. 2 with regards to Fuller (1992)). Hevner et al. (2004) conclude that "IT researchers must **create innovative IT artifacts** [sic!] that **address important problems**, **demonstrate the capabilities of such artifacts** [sic!], and **evaluate and predict their potential benefits and risks**" (Hevner et al., 2004, p. 2). This is what needs to be considered in the scope of this work when developing the competency model for employees in Industry 4.0 and the prototype curriculum for Industry 4.0.

Section 1.1 contains the motivation and shows the demand in research and practice for implementing these artefacts. The application of Design Science on the implementation projects is described in the following section 3.1.2. Chapters 4 and 5 contain the descriptions of the development and the results of the two artefacts as well as the corresponding evaluations.

Hevner et al. (2004) emphasize that "[d]esign is both a process and a product" (Hevner et al., 2004, p. 3):

> *"It describes the world as acted upon (processes) and the world as sensed (artifacts [sic!]). This Platonic view of design supports a problem solving paradigm that continuously shifts perspective between creating design processes and building design artifacts [sic!] for the same complex problem."* (Hevner et al., 2004, p. 3).

In our opinion, it is very important in the case of building a curriculum to focus on the users' pain points and needs. Therefore, for the implementation of the curriculum for Industry 4.0, which is described in chapter 5, we combine Design Science with the Design Thinking approach as presented in section 3.3, which is a user-centric and creativity supporting approach for problem solving.

3.1.2 Design Science Applied in this Thesis

The goal of this work is to develop a competency model for employees in Industry 4.0 and, building on that, a prototype curriculum for Industry 4.0. As the curriculum builds on the competency model, two iterations of Design Science are needed, starting with the implementation of the competency model.

3.1.2.1 Development of a Competency Model for Employees in Industry 4.0 with Design Science

Figure 9 shows the “framework for understanding, executing, and evaluating design science [sic!] research in [IS]” (Hevner et al., 2004), adjusted to serve the needs of the implementation of the competency model for employees in Industry 4.0. The development of the competency model is described in chapter 4.

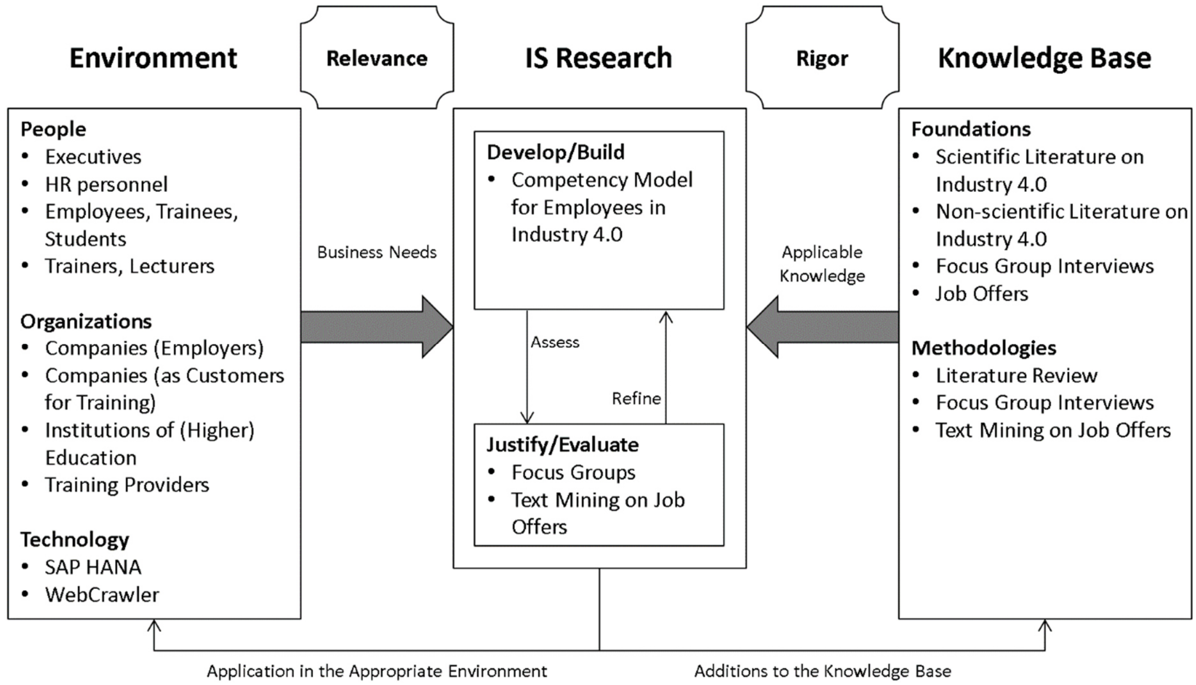

Figure 9: Design Science Framework for the Implementation of the Competency Model for Employees in Industry 4.0 (with regards to Hevner et al. (2004, p. 5))

The “Environment” describes the problem space at hand (Simon, 1996). Hevner et al. (2004) define, that this “Environment” contains “[b]usiness (organizations) and [t]echnology” (Hevner et al., 2004, p. 4 f.). We added the people who have to deal with qualification in an Industry 4.0 environment. This comprise executives (and other stakeholders) and human resources (HR) personnel, who have to decide about the qualification requirements of their company and the training budget. Moreover, it comprises, of course, employees, trainees and students, who represent the learners, and trainers or lecturers who have to present the content, conduct trainings or lectures, and guide the learners through the learning process. As organizations that may be interested in a competency model for employees in Industry 4.0, we identified companies that are in the need for employees with the right qualifications to fulfil their jobs (companies as customers), institutions of (higher) educations, such as universities, universities of applied sciences, schools, and other training providers. The technologies that were used in the development of the competency model for employees in Industry 4.0 are SAP HANA and a web crawler when it comes to the collection and the analysis of online job offers (cp. section 3.7.3.1).

The “Knowledge Base” “provides the materials from and through which artifacts [sic!] are constructed and evaluated” (Hevner et al., 2004, p. 4). In this section, Hevner et al. (2004) locate the theoretical foundations and research methodologies. For the development of the competency model for employees in Industrie 4.0, we conducted a literature review on scientific and non-scientific literature on Industry 4.0 (cp. section 3.4 for methodology and section 4.1.1 for results) to include findings from earlier research. We added the outcomes of focus groups with personnel from academia (cp. section 3.5 for methodology and section 4.1.2 for results), and – to add a practical perspective – we did text mining (TM) on online Industry 4.0-related job offers (cp. section 3.7 for methodology and section for 4.3 results) and added the findings to our model. Table 7 illustrates the Design Science research guidelines proposed by Hevner et al. (2004), adjusted to the development of the competency model for employees in Industry 4.0.

Table 7: Design Science Research Guidelines (with regards to Hevner et al. (2004, p. 7 ff.))

Guideline	Applied in the scope of this thesis
1. Design as an Artefact	– Artefact: An overall competency model for Industry 4.0
2. Problem Relevance	– Currently, it is a challenge for companies to find employees educated adequately for working in Industry 4.0 (Baygin et al., 2016). – There is no overall qualification strategy for Industry 4.0 yet.
3. Design Evaluation	– The first draft of the competency model will be derived from scientific and non-scientific literature. – In the second iteration, results from focus group discussions are added to validate and extend the model. – In a third iteration, results from TM on job offers are used for a second validation and extension of the model.
4. Research Contributions	– Revised and verified overall competency model for Industry 4.0
5. Research Rigour	This research is conducted following best practice methods: – Design Science (Hevner et al. (2004), this section) – Literature Review (vom Brocke et al. (2009), Webster and Watson (2002), and Levy and Ellis (2006), cp. sections 3.4 and 3.6). – Focus Groups (Krueger, Casey, 1994, 2000) combined with the Critical Incident Technique (Flanagan (1954); A. Koch, Strobel, Kici, and Westhoff (2009), cp. section 3.5). – TM on Job Offers (Aggarwal and Zhai (2012), Feldman and Sanger (2006). Jiang (2012), Piskorski and Yangarber (2013), Sarawagi (2008), and others, cp. section 3.7)
6. Design as a Search Process	– We searched for information first in literature, then in focus groups, and then in results from TM on job offers. We tried to discover competencies relevant for Industry 4.0.
7. Communications of Research	– We communicated our research results in two PhD theses as well as in scientific papers and a poster (cp. section 1.4).

3.1.2.2 Development of a Curriculum for Industry 4.0 with Design Science

Along the lines of the framework for the implementation of the competency model for employees in Industry 4.0, Figure 10 presents the Design Science framework adjusted to the implementation of the prototype curriculum for Industry 4.0. The implementation of the prototype curriculum for Industry 4.0 is described in chapter 5.

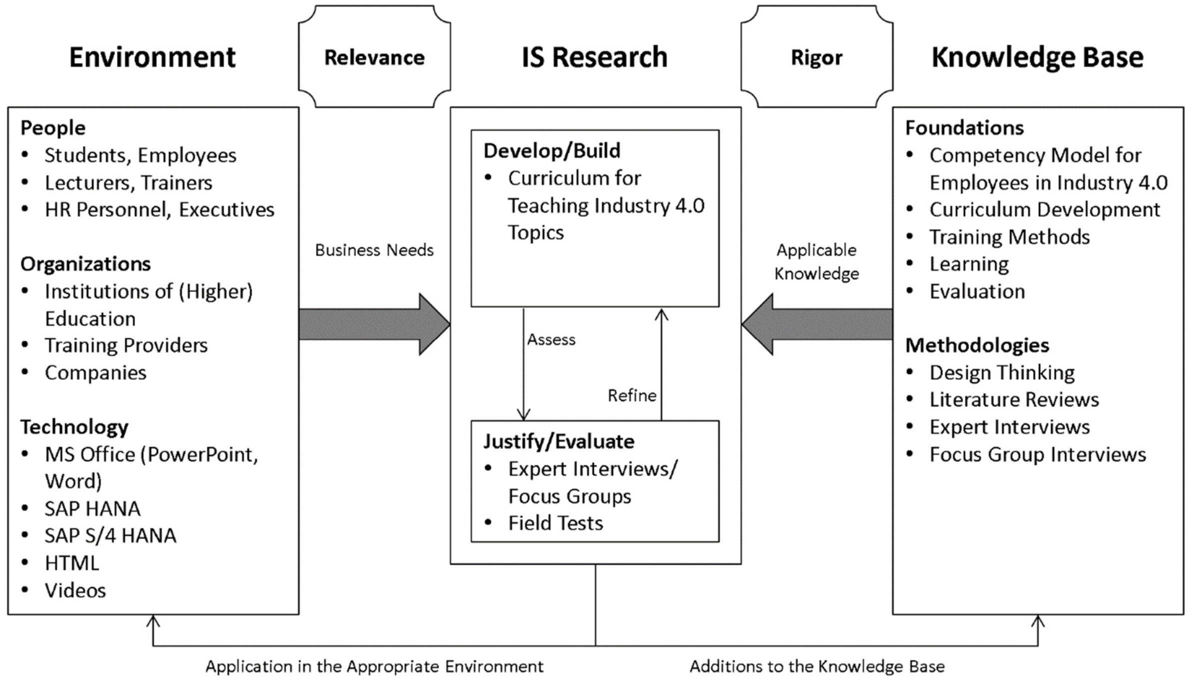

Figure 10: Design Science Framework for the Implementation of the Prototype Curriculum for Industry 4.0 (with regards to Hevner et al. (2004, p. 5)

In the case of the implementation of the curriculum for Industry 4.0, we identified the following stakeholders: students and employees as learners, lecturers and trainers who conduct lectures or trainings, and executives and HR personnel who are in the need of well-qualified employees. As the focus of a competency model for employees in Industry 4.0 is more common than the one of a prototype curriculum for Industry 4.0, which is built in a defined environment for an existing group of customers (cp. sections 3.8.1 and especially 3.8.2.1), we rearranged the order of the groups of people in Figure 10. The organizations relevant for the curriculum are institutions of (higher) education, training providers who may use the curriculum as well as companies who will benefit from the well-trained students when they start working. The main technologies that are used in the curriculum are MS Office products, especially PowerPoint and Word, SAP HANA (cp. section 3.8.3.1), SAP S/4HANA (cp. section 3.8.3.2), HTML[32], and videos.

One important element of the “Knowledge Base” for the curriculum for Industry 4.0 is the formerly developed comprehensive competency model for employees in Industry 4.0. Moreo-

[32] HTML: Hypertext Markup Language.

ver, best practices from scientific literature regarding curriculum development, training methods, learning, and evaluation are considered. As mentioned earlier, during the curriculum development process, the Design Thinking approach as presented in section 3.3 is applied. Design Thinking demands for an ongoing evaluation of prototypes during the whole implementation process. This is done with expert interviews and focus groups as described throughout the curriculum development process in chapter 5. In the next section, we present the RQ of this work.

Table 8: Design Science Research Guidelines (with regards to Hevner et al. (2004, p. 7 ff.))

Guideline	Applied in the Scope of this Thesis
1. Design as an Artefact	– Artefact: An implemented and evaluated curriculum for Industry 4.0
2. Problem Relevance	– Currently, it is a challenge for companies to find employees educated adequately for working in Industry 4.0 (Baygin et al., 2016). – There is no overall qualification strategy for Industry 4.0 yet.
3. Design Evaluation	– Beginning in the conception stage through development and implementation of the learning materials, we evaluated our ideas, drafts, prototypes, and the outcome in several iterations with several user groups (cp. chapter 5).
4. Research Contributions	– Evaluated Industry 4.0 learning materials which can as well serve as subject to further research
5. Research Rigour	This research is conducted following best practice methods: – Design Science (Hevner et al. (2004), this section) – Focus Groups (Krueger, Casey, 1994, 2000) combined with the Critical Incident Technique (Flanagan (1954); A. Koch et al. (2009), cp. section 3.5). – Design Thinking approach (Gekeler, Gürtler, and Kembel (2017), cp. section 3.3) – Online expert interviews.
6. Design as a Search Process	– We made use of the materials, systems, and experiences available in our project context, esp. the SAP UCC, Munich at the TUM, in Garching bei München, Germany (cp. section 3.8.1.1).
7. Communications of Research	– We communicated or research results in two PhD theses as well as in several publications (cp. section 1.4).

3.2 Research Questions

The following three research questions structure this thesis:

RQ1: Which skills and competencies do employees need in an Industry 4.0 environment?

In a first iteration, we develop a competency model for employees in Industry 4.0 based on a literature review on competencies for Industry 4.0 and focus groups conducted with academics. The literature review on competencies for Industry 4.0 is conducted following the guidelines and propositions proposed by vom Brocke et al. (2009), Webster and Watson (2002), and Levy and Ellis (2006) (cp. section 3.4). The focus groups have been carried out with regards to Krueger and Casey (2000) and Krueger and Casey (1994). We took into account ideas from the Critical Incident Technique as proposed by Flanagan (1954) and A. Koch et al. (2009) (cp. section 3.5).

In a second iteration, we first conducted a literature review on competency models with regards to the guidelines proposed by vom Brocke et al. (2009) and Webster and Watson (2002) (cp. section 3.6). We decided to combine the competency model for employees in Industry 4.0 developed in the first iteration with the general competency model described by Erpenbeck in the Handbuch Kompetenzmessung (2007) to create an overall competency model for employees in Industry 4.0 that contains both, Industry 4.0-specific as well as general competencies. Second, we conducted TM on German online job offers to validate and complement our competency model with findings from practice. We applied advices from literature on TM (e.g., Aggarwal and Zhai (2012), Feldman and Sanger (2006). Jiang (2012), Piskorski and Yangarber (2013), and Sarawagi (2008)) as well as literature on analysing job offers (e.g., Harper (2012), Balbi and Di Meglio (2004), Bensberg and Buscher (2016a), Traxler and Greiling (2014), and Sailer (2009); cp. section 3.7). Parts of this second iteration were supported by our master student Sebastian Hagn – and therefore are documented in his master thesis as well (Hagn, 2017). As result of RQ1, a comprehensive competency model for employees in Industry 4.0 is presented (cp. section 4.3).

RQ2: How can competencies for Industry 4.0 be implemented in learning units for (future) employees following best-practice design guidelines?

To address this RQ, we provide a prototype curriculum for Industry 4.0, which deals with significant aspects of Industry 4.0, from technical innovations such as sensors and IoT over effects on business strategies, models and processes to implications on topics such as security and ethics. Thus, we target future employees in different areas affected by Industry 4.0, namely pupils of business colleges, trainees, and students of Economics, Business Informatics, IS, Computer Sciences, Informatics, Engineering, and related subjects. The curriculum was developed in the SAP UCC at TUM in Garching bei München, Germany (cp. section 3.8.1.1). The implementation of IT trainings and curricula as special kind of training has been a topic of intense research, cp. e.g., Compeau et al. (1995); Gupta et al. (2010). Schaper et al. (2012) propose to develop a university curriculum following six phases. These phases were adopted to the curriculum design project in the scope of this work. The curriculum development, intermediate results and the first release of the curriculum for Industry 4.0 are described in chapter 5.

Due to recent technological developments, challenges in developing innovative and attractive curricula for students have risen. Students today are familiar with technologies such as tablets, smartphones, notebooks and connected, interactive applications; they are “digital natives”. This makes them more dynamic in their learning process, as they can access any kind of well-presented information at any time from all kinds of mobile devices. Thus, it is not feasible to present them theories on long slide decks anymore; they expect learning to be motivating, cut into small pieces, and to be an experience. Thus, addressing them in an appealing, targeted language gains more importance as well as including hands-on exercises, gamification approaches, and other interactive elements to catch and hold their attention.

Traditional curriculum development methods found on years of research and experiences. They often offer a rather linear process that does not integrate or encourage creativity during the curriculum development process. In the scope of this curriculum development project, we want to address the expectations of today's students as described before. Therefore, we applied the user-centric and creative Design Thinking approach to our curriculum development to focus on the students' needs and wishes on the one hand – and use the creative approach to develop a more creative and interactive learning experience. Our goal here is not to offer yet another method on curriculum development, since research in the areas of didactics and education already provides well-founded and approved approaches. However, we are convinced that the development of technical curricula can benefit from the application of elements of the Design Thinking approach.

RQ3: Does the proposed prototype curriculum meet the needs of its consumers?

Not only the Design Science approach proposed by Hevner et al. (2004) emphasizes that building an artefact needs evaluation in order to assess if the artefact is suited to fulfil its task and if it meets the requirements derived ahead of its development. Therefore, the development of the curriculum was accompanied by a continuous evaluation of parts of the curriculum at different stages and with different means, such as focus group or expert interviews, in line with the phases Prototype and Test from the Design Thinking approach (cp. sections 3.3 and especially 3.3.2.4 and 3.3.2.5).

The outcome of RQ2 and RQ3 is an Industry 4.0 curriculum ready for application.

3.3 The Design Thinking Approach

Design Thinking is a multidisciplinary, user-centric approach, which offers many methods. It does not necessarily rely on a strict, consistent definition, but offers approaches for solving problems in a creative way that encourages the generation of new ideas for possible solutions.

3.3.1 Historical Development of the Design Thinking Approach

Design Thinking started emerging in the 1970s at Stanford University, USA, in the context of engineering education (C. P. Hoffmann, Lennerts, Schmitz, Stölzle, Uebernickel, 2016). The Design Thinking approach combines the human psychological factors of desirability with the technical factors as feasibility and economic factors as viability (Grots, Pratschke, 2009). In 2002, Schenk (2002) applied an interactive approach that includes steps of Design Thinking for developing a training concept for tele cooperation. In 2003, Kelley, Leifer, and Winograd founded the d.school Stanford at Stanford University in order to support Design Thinking as an approach for solving complex problems (Weinberg, 2017). Hasso Plattner started supporting the Design Thinking approach and founded the Hasso Plattner Institute (HPI) School of Design Thinking in 2007 in Potsdam, Germany (Weinberg, 2017). Since then, Design Thinking became part of teaching at several institutions of higher education in many countries around the world, such as the USA or Germany. Nowadays, several companies use the Design Thinking approach, mainly for the development of new software or products. This comprises companies such as Allianz SE, Audi AG, Ball Packaging Europe, Clariant AG, Deutsche Bank AG, the Fédération Internationale de Football Association (FIFA), Haufe-Lexware GmbH & Co. KG, Merck, SAP

SE, Swisscom AG, Telekom Austria Group, UBS Group AG, or WashTec AG (C. P. Hoffmann et al., 2016).

Kembel (2017a) points out that the Design Thinking approach is not neccesarily the one that directly leads to the best project results. However, applying Design Thinking in a project may increase creativity as well as the learning of new behaviours that differ from getting a problem and focussing on the solution right away – as it is a very user-centric approach. Thus, the first steps in Design Thinking do not deal with finding a quick solution, but with finding out what the user really needs. Kembel (2017a) notes, that this may be an unfamiliar approach in the beginning for many people. From my own experiences while working in the IT department in a bank as well as from working at different customers as IT Consultant, it can be told that this is especially important and helpful for people in technical oriented fields such as IT, IS or engineering. It addresses creativity and a user-centric view, which are often disregarded in a technical oriented environment.

Regarding the Design Thinking approach, there exist different variants of how to execute the process with different numbers of steps. While we will stick to the five-step approach as presented by the d.school at Stanford University and Gekeler et al. (2017) in the following, e.g., Wölbling et al. (2012) describe a version of the Design thinking process which comprises six steps. However, according to Kembel (2017a), all variants focus on the same content and activities. Design Thinking is often presented as process, drafted from the left to the right. Kembel (2017a) proposes to draw it as circle as it can and should be an iterative process (cp. Figure 11 in section 3.3.2). Furthermore, Kembel (2017a) recommends each person or project to choose or even to develop his or its own, case-specific Design Thinking approach, depending on his needs and requirements to get the best results. However, as it fits well to our setting in the scope of the curriculum development project, we stick to the five-step approach proposed by the d.school at Stanford University, as described by Gekeler et al. (2017).

3.3.2 The Five-Step Design Thinking Approach as Proposed by the d.school at Stanford University

The five-step Design Thinking approach proposed by the d.school at Stanford University includes the steps “Empathy”, “Define”, “Ideate”, “Prototype”, and “Test” (Kembel, 2017a, min. 01:07 ff.). It is illustrated in Figure 11 and will be explained in the following. After an initial problem definition, each of those steps builds on the previous one. The results are carried on to the next step. The process may see several iterations.

Gekeler and Gürtler (2017a) emphasize that besides the five steps, also called phases, the composition of the team working on the project is also very important when the Design Thinking approach is applied. As one of the goals of the Design Thinking approach is to creatively generate ideas, it is important to have diverse members in the team, e.g., “customers, managers, designers, [and] developers” (Gekeler, Gürtler, 2017a, min. 01:37 ff.). To get the team started, they propose to invest in teambuilding at the start of the project (Gekeler, Gürtler, 2017a).

Gekeler and Gürtler (2017a) underline the importance of a flexible space for the different Design Thinking activities such as prototyping or presentations. Such a flexible space may be a room where it is possible to rearrange chairs and tables, where it is possible to use the walls as boards, where is enough room for teamwork in small groups, etc.

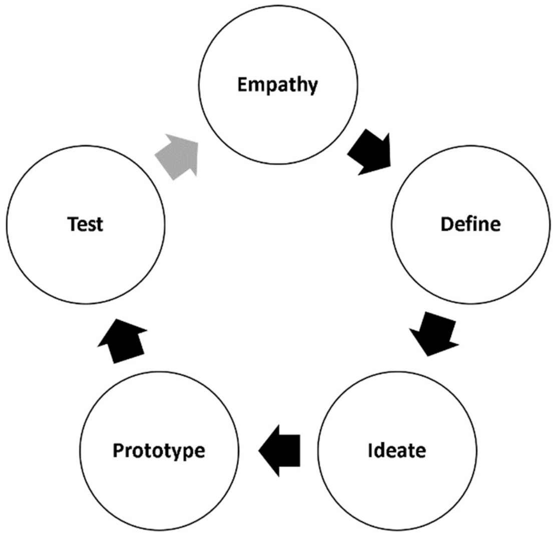

Figure 11: The five-step Design Thinking Approach proposed by the d.school at Stanford University (with regards to (Kembel, 2017a, min. 01:01 ff.))

In the following sub-sections, the five steps proposed by Kembel (2017a) as well as their purposes are explained, before we sketch how Design Thinking was used in our curriculum development project (cp. section 3.3.3). After the development of the curriculum for Industry 4.0, we give a résumé of our experiences with the application of the Design Thinking approach to a curriculum development project (cp. section 5.9).

3.3.2.1 Empathy

In the "Empathy" phase, the project team collects real-world insights and the users' needs. The goal of this phase is not to start thinking of any solutions. Instead, the project members should talk directly to the people affected by the problem that should be solved by the project. It is important to understand their wishes and needs, as well as their points of view (Kembel, 2017a). This should prevent to build solutions based on assumptions of project members instead of on the real requirements of the users, and thus, to generate empathy towards the target group (Kembel, 2017b). It includes observing what people say and do, but goes far beyond this, taking into account implicit aspects as well, such as what people are thinking and feeling (Kembel, 2017b). In addition, it is important not only to observe the "average" user, but to examine the "extreme" and "expert" users as well – as their needs may be the really interesting ones when thinking about how to solve the problem (Kembel, 2017b). After observing, the users may be interviewed. Kembel (2017b) proposes to start with an introduction, developing rapport, seek for stories, explore emotions, understand what this means to the user, and finishing with a wrap up. He suggests to stay listening after the warm up, as interesting aspects may emerge only then. Moreover, he proposes to ask the interviewees to "tell [him] more" (Kembel, 2017b, min. 09:00 ff.), ask "why", and to "be silent and listen" (Kembel, 2017b, min. 09:10 ff.).

3.3.2.2 Define

In the "Define" phase, the insights from the Empathy phase are used to identify or to refine the problem to be solved. The problem definition may differ from that from the starting point of the process (Kembel, 2017a). One element often used in the Define phase is the define statement – or Point of View (PoV) (Kembel, 2017c). It contains information about the user, the user's needs and some insights which should comprise some surprising or unexpected information (Kembel, 2017c, cp. Figure 12). The Define phase starts with collecting the needs and insights discovered in the Empathy phase before. This part is called "Storytelling" as well, as each team member presents his insights collected before to the team (Gekeler, Gürtler, 2017b). Collecting these insights and then clustering them is done "to understand the problems, and the wishes, and the needs" (Gekeler, Gürtler, 2017b, min. 02:11 ff.) of the users.

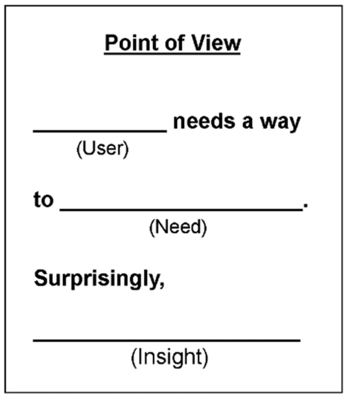

Figure 12: Define Phase – Point of View (PoV)-Template (with regards to Kembel (2017c, min. 04:07 ff.))

A persona describes a (real or fictional) user and his needs and problems including personal attributes, such as name, age, etc., so that the project team can easily identify with this persona (Gekeler, Gürtler, 2017b). An empty template for a persona is shown in Figure 13. In the "About" section, there is room for some personal information about the person. Under his name, there is room for his position or profession and a short, characteristic statement from him. Below, there are the four dimensions "Responsibilities", "Main Goals", "Needs", and "Pain Points" that describe his work and his main problems with it. This is one possible arrangement of a persona. Personas may look different – but should contain information that point out typical characteristics of the person in focus – and make it easy for project members to identify with the person and his needs and

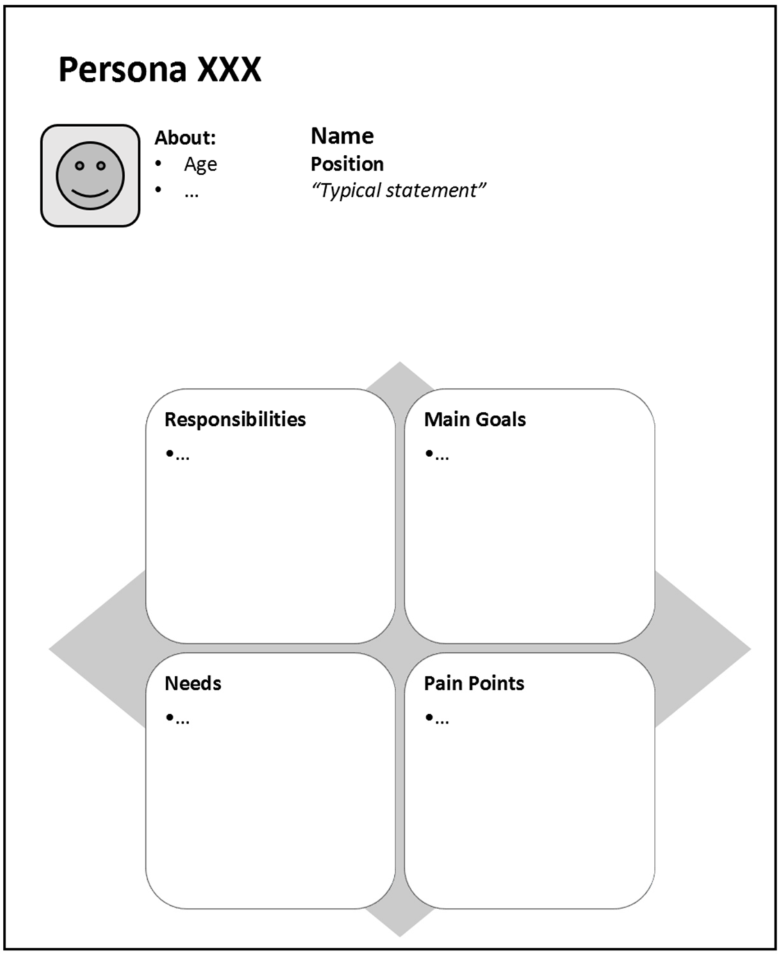

Figure 13: Define Phase – Persona-Template

pain points. Based on personas and findings from the Empathy phase, define statements – or PoVs – are written down which focus on important insights of the personas – or users.

After the definition of different PoV statements and one or more personas, it is part of the Define phase to choose one PoV statement that will serve as foundation of the following phases. Thus, it is decided, which part of the problem is focussed on first. Other PoV statements can be kept for later iterations. The chosen statement should be “tight” and “potent” (Kembel, 2017c, min. 06:04 ff.). It should be able to generate emotionality towards the user. The need of the user should be meaningful. The “unexpectedness of the insight [should be increased]” (Kembel, 2017c, min. 07:16 ff.).

3.3.2.3 Ideate

In the “Ideate” phase, the (re-)defined problem statement chosen in the Define phase is taken as subject. The goal of this phase is to think of as many different and maybe unexpected or even unrealistic options for solving the problem described in the PoV statement as possible (Kembel, 2017a, 2017d). Thereby, the Ideate phase consists of two steps. The focus is not on judging the newly generated ideas immediately. First, a large amount of ideas should be generated without any preferences (Kembel, 2017d). Only in the second step, the ideas generated in the first part of the Ideate phase are discussed and then judged.

In order to creatively generate a large amount of (unexpected) ideas, Kembel (2017d) recommends to setup diverse project teams and to use techniques such as brainstorming. If brainstorming is used, Gekeler and Gürtler (2017c) propose to focus on the user, to defer judgement on the ideas in the stage of idea generation, to engage the whole team in the discussion, to stick to communication rules, and to generate ideas for three categories: most radical ideas, most resonant and appealing ideas, and most relevant ideas (Gekeler, Gürtler, 2017c). Kembel (2017d) emphasizes to encourage wild ideas, building ideas on the ideas of other project team members, and work on and present the ideas visually to the whole team. Like Gekeler and Gürtler (2017c), he proposes to select multiple options with different selection criteria in the end, e.g., safe, meaningful, and radical (Kembel, 2017d).

3.3.2.4 Prototype

The goal of the “Prototype” phase is to create one or more prototypes based on the ideas selected at the end of the Ideate phase. Each prototype should focus on one aspect to be examined and tested. The prototype can be presented to and discussed with potential users in the following Test phase. Instead of building a first, full-functional version of a solution, Kembel (2017a) proposes to build quick-and-dirty low-resolution, and at the same time very cheap prototypes which the user can interact with. E.g., for a mobile application, this may be a paper mock-up made from sticky notes. The testing should take place in a typical surrounding in which the solution may be used in real life later on. The goal of this experimental approach is not to find the “right” and perfect solution, but “to learn as quickly as possible” (Kembel, 2017e, min. 01:24 ff.). Thus, prototypes should not be built in months, but in hours or days. Gekeler and Gürtler (2017d) point out that for prototyping, a space with materials that can be used to build something tangible is helpful to increase creativity.

The quick and dirty prototypes enable the project team to get feedback quickly from users in the Test phase. This allows the project team to get fast feedback on their work. Moreover, a quickly-built prototype avoids that the developers become too emotional about the object at hand and start to defend it when it is criticized (Gekeler, Gürtler, 2017d; Kembel, 2017e). If the prototype has weaknesses, not too much financial means and human effort were spent before. Furthermore, users may provide their feedback more honestly if the prototype was built quick and dirty. Kembel (2017e) proposes to build experiential prototypes, and to "isolate […] [the] variables" (Kembel, 2017e, min. 03:43 ff.), which means to test only one aspect of the solution at a time, e.g., "just the interface or just the process" (Kembel, 2017e, min. 04:08 ff.). He proposes to "iterate as quickly as possible" (Kembel, 2017e, min. 04:17 ff.) to generate new ideas, test them fast, and improve the solution.

3.3.2.5 Test

In the "Test" phase, the prototype from the Prototype phase is tested with users, if possible, in a real world surrounding (Kembel, 2017e). Based on the feedback of the users, a new iteration of the Design Thinking process – or only one of the Prototyping and Test phases – may start (cp. section 3.3.2). In this Test phase, it is important to process the feedback. Kembel (2017e) proposes to note down what worked well, what did not, which question arose and which new ideas emerged.

3.3.3 The Design Thinking Approach Applied in the Curriculum Development Process

Design Thinking is a multidisciplinary approach, which offers a bunch of methods. It does not necessarily rely on a strict, consistent definition, but offers approaches for solving problems in a creative way that encourages the generation of new ideas for possible solutions. In our curriculum development project "The Digital Transformation of Global Bike", we implemented an Industry 4.0 curriculum as a new artefact. The topic "Industry 4.0" was given, the decisions, which contents and training methods should be used were derived in a creative process.

In the past, feedback on new curricula developed by the SAP UCCs (cp. section 3.8.1.1) has mainly be gathered after the curricula have already been developed, tested, and rolled out. Teachers and students have rarely been interviewed for their wishes and needs in advance. In most cases, they have not been part of the development process. However, it is not easy to change curriculum materials in a late stage of development – or even after the rollout, as this may affect all users who are already working with the newly distributed materials as well as the data implementation in the corresponding software systems. Sometimes, this even led to well-implemented curricula that were not accepted by the regular teachers and lecturers connected to the SAP UCCs. To avoid this, we decided to use the Design Thinking approach in our curriculum development project. Our goal was to put the curriculum close to the customers' needs and to be able to benefit from their experiences.

Especially in rather technical fields such as IS, Business Informatics, Informatics, Computer Sciences, or Engineering, experts tend to be real experts for the technical topics. In a curriculum development project, this knowledge needs to be combined with what is needed to build training units or curricula that are appealing to trainers and learners, and well-suited to support and motivate them in their learning process. As the Design Thinking approach is a user-centric and creativity-enhancing one, it addresses aspects, which are often not in the focus of technical oriented people and supports the interdisciplinarity of the project. In our curriculum development project, we stuck to the five-step Design Thinking approach presented by Kembel (2017a). The application of the Design Thinking approach in the project is described throughout chapter 5. The outcomes of the application of the Design Thinking approach are summarized section 5.9. In Table 9, you find a short overview of the Design Thinking activities in the development project.

Table 9: Design Thinking Activities in the Curriculum Development Project

Design Thinking Phase	Activities
Empathy	Focus groups (cp. sections 3.5 and 4.1.2)
Define	Personas and PoVs (cp. section 5.1.1)
Ideate	E.g., development of the overall curriculum structure (cp. section 5.3)
Prototype	Several prototypes at different stages (cp. chapter 5)
Test	Evaluation of the prototypes (cp. chapter 5)

In the beginning of the curriculum development project, we had to decide, what content should be comprised, and how this content could be provided in an appealing way for learners and trainers. We decided to consider the potential customers' knowledge, experiences, needs and pain points right from the beginning – and throughout the whole curriculum development process. Besides conducting a literature review on Industry 4.0 (cp. sections 3.4 and 4.1.1), we conducted focus groups as described in sections 3.5 and 4.1.2 with potential customers of the new curriculum. In this early stage, the only thing that was fixed was the idea of developing an Industry 4.0 curriculum in the scope of the SAP UCC context. We did not only ask the participants of the focus groups which topics they rated relevant in this context, but we wanted to learn about their experiences and pain points with former SAP University Alliances (SAP UA, cp. section 3.8.1.1)/SAP UCC curricula and about their wishes for future ones. Thus, we discussed applied and possible teaching methods, different kinds of learning materials, the level of complexity, etc. Based on the findings from these focus groups, we were able to derive different personas of teaching staff, partially with contrarian opinions. The resulting personas and PoVs are presented in section 5.1.1.

The Design Thinking approach demands for several iterations, especially of prototyping (cp. section 3.3.2.4) and testing (cp. section 3.3.2.5). This is in line with Design Science as proposed by Hevner et al. (2004) (cp. section 3.1.1), who refers to Simon (1996), who "describes the nature of the design process as a [g]enerator/[t]est [c]ycle" (Hevner et al., 2004, p. 13) (cp. Figure 14). The curriculum development process is described in chapter 5. Section 5.2 contains an overview of the prototype artefacts that have been subject to evaluation as well as of the evaluations itself. The evaluations are described throughout chapter 5 together with the descriptions of the developments of curriculum artefacts.

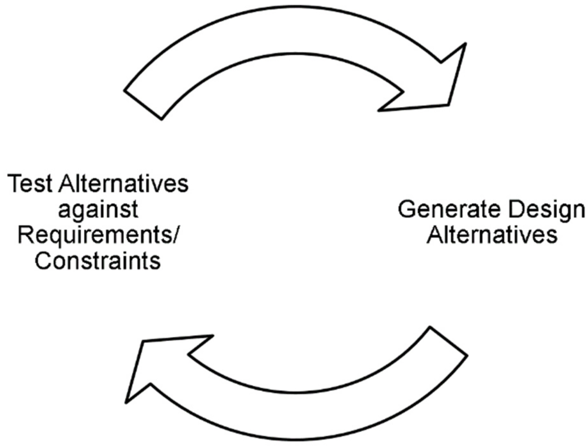

Figure 14: The "Generate/Test Cycle" of Design Science as proposed by Hevner, March, Park, and Ram (2004) (with regards to Hevner et al. (2004, p. 14))

3.4 A Literature Review on Competencies for Employees in Industry 4.0

When we started our research on competency requirements for employees in Industry 4.0, this was still an emerging field. Our first step in identifying competencies relevant for employees in Industry 4.0 was to conduct a systematic literature review. This provided us with an overview of already existing research in the field (vom Brocke et al., 2009). Our goal was to first identify competencies for employees in Industry 4.0, and then to classify them. Therefore, we applied a concept-centric approach as described by Webster and Watson (2002). The results of the literature review were published in Prifti, Knigge, Kienegger, et al. (2017a) and Prifti, Knigge, Kienegger, et al. (2017b). Table 10 contains the keywords that have been used to search the scientific literature in the databases ACM Digital Library, IEEE Xplore Digital Library, SpringerLink and EBSCOHost (Business Source Premier, EconLit, Information Science & Technology Abstracts, Education Source, ERIC, Business Source Complete). By choosing those databases, we ensured to not only include IS literature, but also such from the disciplines of Education, Economics, IT, and Engineering. (Prifti, Knigge, Kienegger, et al., 2017a).

Table 10: Keywords for Literature Review on Competencies for Industry 4.0 (with regards to Prifti, Knigge, Kienegger, et al. (2017a, p. 51))

Keywords	Each Keyword Combined with…
– "Industrie 4.0"	– "Competence"
– "Industry 4.0"	– "Competency"
– "Digital Transformation"	– "Skill"
– "Internet of Things"	– "Knowledge"
– "IoT"	– "Attitude"
– "Cyber Physical Systems"	– "Ability
– "CPS"	– "Value"
	– "Education"

The literature review was conducted in August 2016, and therefore contains publications from August 2016 and earlier. To complete the result list, Google Scholar was used as an additional search database to find further articles that were not found by the structured search in the databases mentioned above, e.g., because they have been published in outlets that are not covered by this set of databases. As a Google Scholar search often leads to a result list with thousands of entries, we sorted the articles by relevance and then screened the first 30 hits for each search string. On the set of articles resulting from these searches, we conducted a backward and forward search as proposed by Webster and Watson (2002). This led to a result set of 3,363 publications. (Prifti, Knigge, Kienegger, et al., 2017a).

As described by Prifti, Knigge, Kienegger, et al. (2017a), the articles from that result set were chosen relevant depending on title and abstract in a first iteration, and on full text in a second iteration. Thus, we reduced our result set to 26 publications. Next, we excluded articles that did not contain specific competencies. By doing so, we ended up with a result set of fifteen scientific papers, which describe specific competencies for Industry 4.0. (Prifti, Knigge, Kienegger, et al., 2017a). As the topic of competencies needed by employees in Industry 4.0 is closely connected to practice, we decided to consider non-scientific literature as well, as proposed by Levy and Ellis (2006). We used Google to search for these kinds of publications. This way, we identified another ten relevant publications from practice, which we then included in our further analysis. Thus, our final result set comprises 25 articles. (Prifti, Knigge, Kienegger, et al., 2017a). The final result list is presented in Table 11.

Table 11: Result Set of Publications from Literature Review on Competencies for Employees in Industry 4.0

No.	Title	Reference
Scientific Papers		
1	"Blending Problem-and Project-Based Learning in Internet of Things Education: Case Greenhouse Maintenance"	Mäenpää, Tarkoma, Varjonen, and Vihavainen (2015)
2	"Educational Challenges for Employees in Project-Based Industry 4.0 Scenarios"	Kiesel and Wolpers (2015)
3	"Towards Curricula for Cyber-Physical Systems"	Grimheden and Törngren (2014)
4	"Training Programs for Excellent Engineers with Engineering of Internet of Thing"	Xia (2011)
5	"Real-Time Cyber-Physical Systems Transatlantic Engineering Curricula Framework"	Grega and Kornecki (2015)
6	"Construction of Hardware Curriculum Group for Transition from Network to Internet of Things Engineering Major"	Chunzhi, Hui, and Xia (2012)
7	"Educational Living Labs: A Novel Internet-of-Things Based Approach to Teaching and Research"	Chin and Callaghan (2013)

No.	Title	Reference
8	"Der Mensch im Mittelpunkt der Fabrik von Morgen"[33]	Richter, Heinrich, Stocker, and Unzeitig (2015)
9	"Conditional Variables of "Ausbildung 4.0" – Vocational Education for the Future"[34]	Zinn (2015)
10	"Zukunft der Facharbeit im Zeitalter „Industrie 4.0“"[35]	Windelband (2014)
11	"Mensch-zentrierte IKT-Lösungen in einer Smart Factory"[36]	Stocker, Brandl, Michalczuk, and Rosenberger (2014)r
12	"Educating the Internet-of-Things Generation"	Kortuem, Bandara, Smith, Richards, and Petre (2013)
13	"Learning in a Mixed Reality System in the Context of "Industrie 4.0""	Guo (2015)
14	"Developments 4.0 Prospects on Future Requirements and Impacts on Work and Vocational Education"	Gebhardt et al. (2015)
15	"Tangible Industry 4.0: A Scenario-Based Approach to Learning for the Future of Production"	Erol, Jäger, Hold, Ott, and Sihn (2016)
Publications from Practice		
16	"Man and Machine in Industry 4.0: How will Technology Transform the Industrial Workforce Through 2025?"	Lorenz, Rüßmann, Strack, Lueth, and Bolle (2015)
17	"Industry 4.0 – The Capgemini Consulting View: Sharpening the Picture beyond the Hype"	Bechtold, Lauenstein, Kern, and Bernhofer (2015)
18	"Securing the Future of German Manufacturing Industrie – Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0 – Final Report of the Industrie 4.0 Working Group"	Kagermann et al. (2013)
19	"Skills for Digital Transformation"	Hoberg, Krcmar, Oswald, and Welz (2017)
20	"Industry 4.0"	Smit et al. (2016)
21	"Industry 4.0: The new Industrial Revolution – How Europe will Succeed"	Blanchet, Rinn, von Thaden, and de Thieulloy (2014)
22	"The 10 Skills you Need to Thrive in the Fourth Industrial Revolution"	Gray (2016)
23	"Industry 4.0 – A Discussion of Qualifications and Skills in the Factory of the Future: A German and American Perspective"	Gehrke et al. (2015)
24	"Kompetenzentwicklungsstudie Industrie 4.0: Erste Ergebnisse und Schlussfolgerungen"[37]	Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016)

[33] Man in the Centre of Tomorrow's Factory. Translated by the author.
[34] "Ausbildung 4.0": "Education 4.0". Translated by the author.
[35] Future of Skilled Work in the Era of "Industry 4.0". Translated by the author.
[36] Human-Centric ICT-Solutions in a Smart Factory. Translated by the author.
[37] Competency Development Study Industry 4.0: First Results and Conclusions. Translated by the author.

No.	Title	Reference
25	“Skills Needs Analysis for “Industry 4.0” based on Roadmaps for Smart Systems”	Hartmann and Bovenschulte (2013)

We extracted competencies for employees in Industry 4.0 from these articles and added them to a concept matrix as proposed by Webster and Watson (2002) (Prifti, Knigge, Kienegger, et al., 2017a). The results of this literature review build one part of the foundation of our competency model for employees in Industry 4.0 They are described, discussed, and published in Prifti, Knigge, Kienegger, et al. (2017a) and in section 4.1.1.

3.5 Focus Group Interviews

In order to validate and to extend our findings from the literature review, we conducted focus groups with customers of the SAP UCCs (cp. section 3.8.1). At the same time, we used those focus groups to get to know the needs and pain points of the potential customers of the Industry 4.0 curriculum to be developed. These activities were part of our Empathy phase.

As described by Prifti, Knigge, Kienegger, et al. (2017a), we conducted four focus groups following the approach of Krueger and Casey (1994) and Krueger and Casey (2000). The focus groups enabled us to talk with several customers at a time while not restricting them by using a narrow-structured survey or interview guidelines. The interviews took place in summer 2016 and lasted 45 minutes on average. Each group consisted of 18 – 25 participants. These comprised academic/teaching staff from institutions of (higher) education from the fields of Economics, Business Informatics/IS, Informatics/Computer Sciences, and Engineering, all members of SAP UA program. Some of the participants had experiences from practice as well. The participants were recruited out of the SAP UCC’s customers’ community: three groups of lecturers from the EMEA region (Europe, Middle East, and Africa), who took part in train-the-trainer sessions for lecturers at the SAP UCC at TUM in Garching bei München, Germany; one group consisting of speakers for the SAP UCC’s customers’ community from the DACH[38] region, which was interviewed in Walldorf, Germany. Thus, the participants of each group knew each other before which helped to reduce reservation and resistance in the discussions. (Prifti, Knigge, Kienegger, et al., 2017a).

The participants were encouraged to discuss their needs for being able to conduct good lectures in their future teaching, e.g., for teaching emerging topics such as Industry 4.0. Topics they would like to integrate in their teaching included technical topics as well as soft skills, which they rated as becoming more important. They expressed how they would like to see the topics implemented in teaching materials – e.g., with hands-on exercises using sensors or students’ smart phones. Moreover, they talked about their experiences with the SAP UCCs’ existing curricula, what they liked – and what could be improved from their point of views. To ensure comparability, the same person conducted all focus groups the same way, with the same intro-

[38] DACH region: D – Deutschland (Germany), A – Austria (Latin name), CH – Confoederatio Helvetica (Switzerland, Latin name.

duction to the topic. As described in Prifti, Knigge, Kienegger, et al. (2017a), we used the Critical Incident Technique (CIT) as proposed by Flanagan (1954) and A. Koch et al. (2009) to develop the guidelines for the focus groups. The introduction to each interview started with "typical work scenarios and products of I[ndustry] 4.0. Then questions were asked about the competencies that employees should bring in Engineering, IT[,] and IS to efficiently work in this scenario" (Prifti, Knigge, Kienegger, et al., 2017a, p. 52). (Prifti, Knigge, Kienegger, et al., 2017a).

All four focus groups were recorded and transcribed for further analysis. The "transcripts [were coded] using the software MAXQ[D]A[[39]][,] and […] [combined using] an inductive with a deductive coding approach. […] [W]e took the competencies from literature as codes and started coding the transcripts. If a new competency was mentioned in a focus group [interview] that was not part of the codes, we used this as a new code meaning a new competency in our list" (Prifti, Knigge, Kienegger, et al., 2017a, p. 52). Two different researches executed the coding independently. Afterwards, we compared and discussed the results until a common understanding was reached. The results of these focus groups build the second part of the foundation of our competency model for employees in Industry 4.0 They are described, discussed and, published in Prifti, Knigge, Kienegger, et al. (2017a), Prifti, Knigge, Kienegger, et al. (2017b), and in section 4.1.2.

3.6 A Literature Review on Competency Models

For getting an overview of competency models and frameworks, we conducted a second literature review following the guidelines of vom Brocke et al. (2009) in 2017. We decided to search scientific literature on this topic: top-ranked journal and conference articles (Webster, Watson, 2002, p. xvi). To identify these, we used the WI-Orientierungslisten of the WKWI (U. Frank, Heinzl, Schoder, 2008). The result list of relevant journals and conference is presented in Table 12. (Hagn, 2017).

Table 12: Top-Ranked Journals and Conferences in IS (with regards to U. Frank et al. (2008, p. 160 ff.))

Journal/ Conference	Title
Journal	ACM Transactions Journal (ACMT)
Journal	Communications of the Association for Computer Machinery (CACM)
Journal	Decision Support Systems (DSS)
Journal	Electronic Markets (EM)
Journal	European Journal of Information Systems (EJIS)
Journal	Human-Computer Interaction (HCI)
Journal	Information and Organization (I&O) (Accounting, Management, & IT from 1995 – 2000)

[39] MAXQDA: software provided by VERBI GmbH, for computer-based qualitative data and TA, e.g., for analysing interviews. MAXQDA can be used in qualitative, quantitative, and mixed-methods research. https://www.maxqda.de/. Accessed on July 29th, 2018.

Journal/ Conference	Title
Journal	IEEE Software
Journal	IEEE Transactions Journals (IEEET)
Journal	Information & Management (I&M)
Journal	Information Systems (ISYS)
Journal	Information Systems Journal (ISJ)
Journal	Information Systems Research (ISR)
Journal	Informing Science Journal (INFSJ): The International Journal of an Emerging Trans-discipline
Journal	International Journal of Information Management (IJIM)
Journal	Journal of Information Technology (JIT)
Journal	Journal of Management Information Systems (JMIS)
Journal	Journal of Strategic Information Systems (JSIS)
Journal	Journal of the Association of Information Systems (JAIS)
Journal	Management Information Systems Quarterly (MISQ)
Journal	Management Science (MS)
Journal	Organization Science (OS)
Journal	Wirtschaftsinformatik (WI)
Konferenz	European Conference on Information Systems (ECIS)
Konferenz	International Conference on Information Systems (ICIS)
Konferenz	Wirtschaftsinformatik (WI)

The online search DBs were chosen in a way that all the outlets listed in Table 12 were comprised: ACM Digital Library, AISeL, EBSCOHost, IEEE Xplore, ScienceDirect, and SpringerLink. However, the search in these DBs was not limited to these top-ranked outlets. In the literature search, we searched for the keywords “competence framework” or “competency framework” or “competence model” or “competency model” in titles and abstracts. We further restricted our search to articles that contained at least one of the terms “industry” or “manufacturing”, “engineer”, or “Digital Transformation”. Our search resulted in 833 hits. In the next step, we classified all articles that contained descriptions of competency models for individuals (not only organizations) with more than one category as relevant. This led to a result set of seventeen articles. With backward search as proposed by Webster and Watson (2002), eight more articles were added. A forward search following the propositions of Webster and Watson (2002) led to one more article, so that we ended up with a total of 26 articles. (Hagn, 2017).

We then used the same search terms in a Google Search to discover relevant articles from practice. We analysed the hits from the first three result pages. All competency models we found relied on the already identified general competency model of the US Department of Labor, Employment and Training Administration, presented in Advanced Manufacturing Competency Model (2010). As it comes close to our working context, only the publication Advanced Manufacturing Competency Model (2010) is considered in our further analysis. Thus, in total we identified 27 sources in our literature review on competency models, a list of which is given in Table 13. (Hagn, 2017).

Table 13: Result Set of Publications from Literature Review on Competency Models and Frameworks: Concept Matrix (with regards to Hagn (2017, p. 16 f.) and Webster and Watson (2002, p. xvii))

No.	Title	Concepts					References
		Industry 4.0	General	Industrial Sector	Job/ Level	Focus on Special Competencies	
1	"Kompetenzentwicklungsstudie Industrie 4.0: Erste Ergebnisse und Schlussfolgerungen" [40]	X		X			Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016)
2	"Competencies Required for Successful Acquisition of the Next Generation Air Transportation System"			X	X		Armstrong and Henry (2009)
3	"The Great Eight Competencies: A Criterion-Centric Approach to Validation"		X				Bartram (2005)
4	"Competence Assessment as an Expert System for Human Resource Management: A Mathematical Approach"		X				Bohlouli et al. (2017)
5	"The Competent Manager: A Model for Effective Performance"		X				Boyatzis (1982)
6	"Linking Intellectual Capital and Competitive Advantage: A Cross-Firm Competence Model for North-East Italian SMEs in the Manufacturing Industry"			X			Camuffo and Comacchio (2005)
7	"In a Search for Competent Engineers… Competence Framework in the Field of Sustainable Manufacturing"			X			Cerinšek and Dolinšek (2011)
8	"Coaching Valuable Systems Engineering Behaviors [sic!]"			X	X		Derro and Jansma (2008)
9	"Georgia's Competency Dictionary: DOAS Human Resources Administration"			X			Georgia's Competency Dictionary (2012)
10	"Tangible Industry 4.0: A Scenario-Based Approach to Learning for the Future of Production"	X		X			Erol et al. (2016)
11	"Handbuch Kompetenzmessung: Erkennen, Verstehen und Bewerten von Kompetenzen in der Betrieblichen, Pädagogischen und Psychologischen Praxis" [41]		X				Handbuch Kompetenzmessung (2007)

[40] Competency Development Study Industry 4.0: First Results and Conclusions. Translated by the author.
[41] Reference Book for Competency Measurement: Understanding and Evaluation of Competencies in Operational, Pedagogic, and Psychologic Practice. Translated by the author.

No.	Title	Concepts					References
		Industry 4.0	General	Industrial Sector	Job/ Level	Focus on Special Competencies	
12	"The Comparison of R&D Personnel Competency in Different Technology Innovation Strategies: Case Study of High-Tech Enterprise"			X	X		Hu, Yang, and Ning (2011)
13	"If You Want Good Systems Engineers, Sometimes You have to Grow Your Own!"			X	X		Derro (2007)
14	"Leadership Competency Assessment of Chinese Technology Entrepreneurs"		X			Leadership	Jin, Lv, and Yan (2006)
15	"A Review of Human Competence in Educational Research: Levels of K-12, College, Adult, and Business Education"		X				Kim et al. (2007)
16	"Learning Apart and Together: Towards an Integrated Competence Framework for Sustainable Entrepreneurship in Higher Education"		X			Entrepreneurship, Sustainability	Lans, Blok, and Wesselink (2014)
17	"Measuring the Useful Skills in a Training Programme"			X	X	Collection of Skills	Lavarde and Marchandon (2013)
18	"Exploring High-Performers' Required Competencies"		X				Lee (2010)
19	"Pathways to Cleaner Production in the Americas II: Application of a Competency Model to Experiential Learning for Sustainability Education"			X			McPherson et al. (2016)
20	"A Competency Model for "Industrie 4.0" Employees"	X					Prifti, Knigge, Kienegger, et al. (2017a)
21	"Academia and Practitioner Perspectives on Competencies Required for Technical and Vocational Education Students in Malaysia: A Comparison with the ASTD WLP Competency Model"						Salleh, Sulaiman, Mohamad, and Sern (2015)
22	"Competence at Work: Model for Superior Performance"		X				Spencer and Spencer (1993)
23	"Building Blocks Model"		X				Building Blocks Model (2017)
24	"Advanced Manufacturing Competency Model"			X			Advanced Manufacturing Competency Model (2010)
25	"Industry 4.0 - A Discussion of Qualifications and Skills in the Factory of the Future: A German and American Perspective"	X		X	X		Gehrke et al. (2015)

No.	Title	Concepts					References
		Industry 4.0	General	Industrial Sector	Job/ Level	Focus on Special Competencies	
26	"The Measurement of Humanware Readiness in a Technology Transfer Process: Case Study in an Electrical Machinery Company"		X				Wiratmadja, Sunaryo, Syafrian, and Govindaraju (2014)
27	"Competency Mapping of Engineers in the Engineering Industry of Satara, Maharashtra"			X			Yadav and Nalawade (2012)

The results of this literature review are part of the foundation of our second version of the competency model for employees in Industry 4.0. They are described, and discussed in Hagn (2017) and in section 4.2.

3.7 Text Mining on German Online Job Offers

For examining changes in competency requirements for jobs, Harper (2012) proposes to analyse job offers. Application examples have been described by Balbi and Di Meglio (2004), Bensberg and Buscher (2016a), and Traxler and Greiling (2014). Sailer (2009) points out the advantage of job offers which are publicly available and show the immediate needs of companies. In order to discover changes in competency requirements over time, it is necessary to collect a large set of job offers over a longer period. Harper (2012) emphasises that the manual effort is very large. (Hagn, 2017).

Therefore, we decided to implement applications for collecting online job offers automatically, as well as for analysing the result set of documents. This approach enables us to collect a large number of job offers and to analyse the resulting data set systematically by applying TM technologies on a new application area.

3.7.1 Job Offers

The main goal of job offers is to attract the attention of potential candidates for a specific job in a specific company (Ehrenheim, 2010). A second goal may be employer branding: the positioning of a company as attractive employer (Nielsen, Luttermann, Lévy-Tödter, 2017). German job offers usually contain five sections: presentation of the employer company, description of the job, profile of requirements of potential applicants, service offers of the employer company, and information regarding the application process (Gansel, 2007). Typical requirements for applicants are educational background, experiences and knowledge, qualification, and competencies (2017). The design and order of the elements in a job offer differ. While some contain texts with full sentences, others contain only headwords (Sailer, 2009). (Hagn, 2017).

In the scope of this work, we concentrated on extracting skill and competency requirements for job applicants from German online job offer portals.

3.7.2 Text Mining

The goal of TM is to extract useful information from data by finding and analysing interesting patterns (Aggarwal, Zhai, 2012; Feldman, Sanger, 2006). The data – texts in a collection of different documents – is not – or only loosely – structured. The texts may be in natural language. Therefore, TM requires pre-processing, which brings the text in a specified, normalized format (Feldman, Sanger, 2006). Second, information is extracted from the texts, e.g., for pattern, knowledge, or trend discovery. Third, the presentation of the results is prepared.

3.7.3 Project Setting

For building the data foundation for our research, we started to collect online job offers on a monthly base manually. Later, we automated this process and collected online job offers on a weekly base. The job offers were collected from the German versions of the online job portals Monster Worldwide[42] and StepStone[43] using the search term “Industrie 4.0”. We decided to use Monster Worldwide and StepStone as they belong to the most-visited ones in Germany (Institute for Competetive Recruiting, 2016). Moreover, they are in the lead with communicating job offers and successful hiring processes (Dannhäuser, 2015). (Hagn, 2017). Both, the monthly and the weekly collected data sets, focus on German online job offers only.

For analysing the job offers, we decided to implement an application based on SAP HANA (cp. section 3.8.3.1). This was an obvious approach as we already had SAP HANA skills and experiences in our team and the possibility to use the SAP HANA infrastructure available in the scope of the SAP UCC at TUM (cp. section 3.8.1.1) as backup. However, in order to get access to a powerful environment including an up-to-date SAP HANA instance together with technical support, we successfully applied for a project environment at the Future Service-Oriented Computing (SOC) Lab of the HPI in Potsdam, Germany (Knigge, Prifti, et al., 2020; Knigge, Prifti et al., unpublished). The technical development environment is described in section 3.7.3.1. In three terms (winter 2016/2017, summer 2017, and winter 2017/18) we were able to use this environment for our research on analysing job offers (Knigge, Prifti, et al., 2020; Knigge, Prifti et al., unpublished; Knigge, Willnecker, et al., 2020).

3.7.3.1 System Architecture

The development environment provided by the HPI comprised a SAP HANA (cp. section 3.8.3.1) Support Pack Stacks (SPS) 12 with 1 terabyte (TB) of Random Access Memory (RAM) and 32 Central Processing Unit (CPU) cores. During our project, the SAP HANA instance was

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[42] Monster Worldwide: Online job portal provided by Monster Worldwide, Inc. https://www.monster.com and Monster Worldwide Deutschland GmbH. https://www.monster.de/. Accessed on July 30th, 2018.

[43] StepStone: German online job portal provided by StepStone GmbH. https://www.stepstone.com/ and StepStone Deutschland GmbH. https://www.stepstone.de/. Accessed on July 30th, 2018.

upgraded to SAP HANA 2 SPS01. In combination, we used the SAP HANA Predictive Analytics Library (PAL) provided by SAP SE and the Eclipse-based SAP HANA Studio, version 2.3.10. For being able to use the SAP HANA Text Analysis (TA) functionalities including predefined configurations, we needed to import the deliver unit "HANA_TA_CONFIG.tgz". (Hagn, 2017; Knigge et al., unpublished).

In the first iteration, we collected job offers manually on a monthly base from November 2016 to April 2017. For uploading them into SAP HANA, we implemented a script in Python, version 3.5.2, using the module "pyhdb", version 0.3.2 (for the script, cp. appendix A). (Hagn, 2017; Knigge et al., unpublished).

In the second iteration, we implemented a web crawler for collecting job offers on a weekly base and uploading them into SAP HANA. The web crawler was implemented using node.js version 6.9.5 Long Term Support (LTS), which is available in SAP HANA 2.0 SPS00 or higher. The crawler is implemented as standalone application outside of HANA, but it communicates with SAP HANA for the upload of the data. In total, the web crawler comprises the download of the job offers from the online job portals as well as the upload into SAP HANA tables. The source code of hxe-jobutil.js and the corresponding files can be found in appendix B.2. The web crawler was scheduled to run on a virtual Windows Server 2012 R2 machine every Monday at 00:00 am from December 11th, 2017 to August 13th, 2018. Thus, it collected data for eight months on a weekly base. The Windows Task Scheduler called the batch file CrawlerAutorunAllPlatforms.bat (cp. appendix B.1.1) without further arguments. This file called the start file of the web crawler, hxe-jobutil.js (cp. appendix B.2.1), twice with the following arguments:

1. "Industrie 4.0" --platform stepstone --limit 1000
2. "Industrie 4.0" --platform monster --limit 1000

Thus, the web crawler was executed twice each week. First, it collected job offers from StepStone containing the German term "Industrie 4.0", then from Monster Worldwide. In both cases, the first 1,000 hits were considered to make sure that the crawlers would finish their search after a certain amount of time. Moreover, manually executed checks resulted in only some hundreds of results. Unfortunately, the collection of job offers from Monster Worldwide was only working until the end of 2017, afterwards, due to changes in the structure of the website our script was not working anymore. Only job offers with unique IDs were uploaded into SAP HANA. Thus, duplicates in this data set can only exist within data from different sources. As there were only 69 job offers collected from Monster Worldwide, we did not find any duplicates in this data set.

3.7.3.2 Data Set 1: Manually Collected Job Offers

Our first data set comprised the manually collected online job offers. It contained 2,470 job offers, collected from November 2016 – April 2017. An overview of the dataset is presented in Table 14.

Table 14: First Iteration: Job Offers from German Online Portals Collected Manually (with regards to Hagn (2017, p. 44))

Period	Monster	StepStone	
November 2016	178	100	
December 2016	271	250	
January 2017	210	175	
February 2017	234	174	
March 2017	231	176	
April 2017	273	198	**Total**
Total	**1,397**	**1,073**	**2,470**

The job offers were stored as HTML or PDF files. Two examples can be found in appendices C.1 and C.2. In both formats, the original texts and formats are stored. No changes were done to the documents.

3.7.3.3 Data Set 2: Data Collected by the Web Crawler

In the second iteration of the analysis of job offers, we used the job offers collected by the Web Crawler from December 11^{th}, 2017 to August 13^{th}, 2018 from the German versions of the online job portals Monster Worldwide and StepStone (cp. section 3.7.3.1). Due to the changes in the structure of the Monster Worldwide website, our data set only contains 69 job offers from Monster Worldwide from December 2017. In this iteration, all job offers were saved as HTML files and directly uploaded into a SAP HANA table. The collection took place on a weekly base, starting each Monday morning at 00:00 a.m. The resulting data set contains 4,268 job offers, which are presented in Table 15. The data set does not contain any duplicates.

Table 15: Second Iteration: Job Offers from German Online Portals Collected Via Web Crawler

Period	Monster	StepStone	
December 2017	69	362	
January 2018	–	414	
February 2018	–	544	
March 2018	–	564	
April 2018	–	573	
May 2018	–	416	
June 2018	–	425	
July 2018	–	539	
August 2018	–	362	**Total**
Total	**69**	**4,199**	**4,268**

3.7.4 Text Mining on Job Offers Using SAP HANA

The TM we executed in the scope of this project is described in detail in Hagn (2017), Knigge, Prifti, et al. (2020), and Knigge et al. (unpublished). In this section, a short overview is given.

SAP HANA offers linguistic TA functionalities, which comprise the most important pre-processing methods segmentation/tokenization, stemming, and part-of-speech (POS)-tagging (SAP SE, 2017d). Segmentation/tokenization analyses the distribution of the continuous characterband into specific segments, e.g., chapters, sections, sentences, words, punctuation marks (Feldman, Sanger, 2006). The smallest syntactical elements – words and punctuation marks – are called "tokens" (SAP SE, 2017c; Simões, Galhardas, Coheur, 2009). Stemming is the identification of the stem of a word – the basic form of a word (SAP SE, 2017d). POS-tagging assigns a tag to each token. This tag describes the grammatical role of the token in the specific context. The number of tags is specific for each TA system (Feldman, Sanger, 2006; SAP SE, 2017d). Moreover, in SAP HANA the tags are dependent on the language used (SAP SE, 2017d). (Hagn, 2017).

3.7.4.1 Information Extraction

Information extraction (IE) is a complex method for extracting facts from unstructured text. It is a subarea of natural language processing (NLP) and an important pre-processing method for TM (Feldman, Sanger, 2006). Some TM algorithms build on the results of IE (Aggarwal, Zhai, 2012). IE identifies pre-defined information types in a specific domain. In this case, a domain is a defined set of text(s) combined with specific information needs (Piskorski, Yangarber, 2013). (Hagn, 2017).

For the extraction of requirements for employees in Industry 4.0, we used a basic IE functionality: named entity recognition (NER). A lot of more complex IE tasks rely on a well-implemented NER (Jiang, 2012). A "named entity" is a sequence of words which describe an entity in the real world (Jiang, 2012), e.g., "United States of America". NER is used to recognize these entities and to classify them in predefined categories, e.g., "person" or "organization" (Jiang, 2012). Moreover, it includes the lemmatization, i.e., the normalization of the named entities (Piskorski, Yangarber, 2013). E.g., for the "United States of America", this would include "USA", "U.S.", "US of America", etc. NER can be implemented with rule-based or statistical methods (Jiang, 2012). Regarding the extraction of requirements for employees in Industry 4.0, it is important to extract different dictions and synonyms as well (Jiang, 2012; Sarawagi, 2008). While rule-based methods are better suited for limited domains, statistical methods are more appropriate for open domains (Sarawagi, 2008). While scientific research focusses on statistical methods as they do not require domain knowledge and as they are suited to reduce human effort, rule-based methods are dominating in practice (Chiticariu, Li, Reiss, 2013). The TA methods provided by SAP HANA offer a rule-based IE (SAP SE, 2017c). (Hagn, 2017).

3.7.4.2 Customer Dictionaries

For analysing the data, we implemented customer dictionaries as well as customer extraction rules (cp. section 3.7.4.3). A user dictionary contains a user-defined collection of entities (SAP SE, 2017c). In the SAP HANA repository, it is saved as XML file with the ending hdbtextdict (cp. e.g., appendix D.12). The dictionary contains entities that are classified in categories. They have exactly one standard name and may have several variant names, e.g., "United States of America" is an organisation (entity category), a state (entity sub-category) and has the variants

"U.S. of America", "U.S.", "USA", etc., whereas "U.S." and "USA" are marked as abbreviations. In the scope of our project, we implemented dictionaries for competencies, educational background, and experiences (Hagn, 2017).

The dictionary for competencies is stored as COMPETENCIES.hdbtextdict (cp. appendix D.1.2). It contains all competencies that are contained in the combined competency model presented in section 4.2.2. Each competency represents the standard name for one entity and is expanded with variants (alternative dictions and/or synonyms). For amplifying the entities with variants, first, terms from the competency model proposed by Erpenbeck in the Handbuch Kompetenzmessung (2007) were taken over, which are not contained in the combined competency model (cp. section 4.2.2). Second, further synonyms meaningful in the scope of job offers were added with the help of the German online dictionary DUDEN (DUDEN, 2018). Third, we used the LINGUISTIC search provided by SAP HANA to find further variants with the same word stem (SAP SE, 2017a). An example is given in appendix D.2.5. The LINGUISTIC search is case insensitive and offers the use of wildcards. The "SNIPPETS" functionality returns not only the result as word, but an excerpt of the text, which enables a concordance analysis (Dzudzek, Glasze, Mattissek, Schirmel, 2009). The concordance analysis enables us to check, if the result of the LINGUISTIC search really describes a variant of a competency. Additionally, further new competency requirements may be discovered, which have not been part of the competency model so far, as competency requirements are often mentioned closely to one another in job offers. (Hagn, 2017).

Another means to discover new competencies is the targeted search for nouns that may represent competencies, e.g., "… ability" or "ability to …". An example is given in appendix D.2.6. (Hagn, 2017). With these kinds of analyses, we were able to identify five new competencies from our first data set and nine new competencies from our second data set. Their integration into our competency model is described in section 4.3.2.

Regarding the educational background, two dictionaries were implemented: EDUCATION.hdbtextdict (cp. appendix D.1.3) and FIELD_OF_STUDY.hdbtxtdect (cp. appendix D.1.5). EDUCATION.hdbtextdict contains the general educational level, e.g., the specific kind of graduation. All entities comprised in this dictionary belong to the category "EDUCATION". FIELD_OF_STUDY.hdbtextdict comprises study subjects that are mentioned in job offers. We took those over from the German Statistical Federal Office (Bildung und Kultur, 2015). All entities in this dictionary belong to the category "STUDY". Moreover, we took over the subcategories "Engineering", "Law, Economics, and Social Sciences", "Mathematics and Natural Sciences", and parts of "Human Sciences". For experiences, domain knowledge is integrated in the dictionary COMPETENCIES.hdbtextdict (cp. appendix D.1.2), while EXPERIENCES.hdbtextdict (cp. appendix D.1.4) contains practicals, international or job experiences (entity category "EXP"). (Hagn, 2017).

The use of customer dictionaries faces some limitations. Apart from simple synonyms, it is complex, time-consuming, and therefore costly to include certain variants of terms, e.g., when they are described with adjectives. A second weakness of the use of custom dictionaries is that only the last part of enumerations is recognized (e.g., “IT and technology affinity” → “technology affinity” instead of “IT affinity” AND “technology affinity”). Third, when working with dictionaries, the context of a term is not considered. E.g., it makes a difference, if a competency appears in the section of a curriculum vitae (CV) in which the author of the document describes his skills and knowledge, or in the description of a project that he was part of – which does not mean that he himself had to deal with every aspect of that project. (Hagn, 2017).

3.7.4.3 Customer Extraction Rules

To address the disadvantages of custom dictionaries, customer extraction rules can be used. They represent the second means to individually customize the entity extraction process in SAP HANA (SAP SE, 2017c). Customer extraction rules are suited for more complex purposes than customer dictionaries (SAP SE, 2017b). In SAP HANA, customer extraction rules are implemented using the “Custom Grouper User Language” (CGUL) and saved as a file with the ending .hdbtextrule (cp. appendices D.1.7 and D.1.8[44]). The custom rules contain patterns that are used in the extraction process to identify entities. These patterns comprise regular expressions and linguistic attributes. Regular expressions are character- or token-based. Token comprise linguistic expressions, such as words or punctuation marks, as well as their linguistical properties (SAP SE, 2017c). These tokens comprise three feels: string, STEM and POS-tags. A string is a word or a regular expression that defines a word. STEM is the word stem or a regular expression that defines a word stem. Which POS-tags are available for a language is documented by SAP SE (2017d). Example token: <STEM: be, POS: V>: this represents every token with the word stem “be” and which is a verb, e.g., “am”, “are”, “is”, “was”, were”, etc. More details can be found in SAP HANA (SAP SE, 2017c). (Hagn, 2017).

For the extraction of competencies from online job offers, we implemented the customer extraction rules COMPETENCIES.hdbtextrule (cp. appendix D.1.7). The extraction rules consider that competencies may be contained in job offers as nouns, adjectives, or predicates. Moreover, they consider enumerations. More, especially technical details can be found in Hagn (2017). For the extraction of linguistic skills, we added the lexicon file GERMAN-LANGUAGES.hdbtextlexicon (cp. appendix D.1.6), which comprises a list of 107 languages (in German language). (Hagn, 2017). Extraction rules for experiences are implemented in EXPERIENCES.hdbtextrule (cp. appendix D.1.8). This enables us, e.g., to extract the duration of work experiences (e.g., “5 years of work experience”). (Hagn, 2017).

Although customer extraction rules lead to better results than customer dictionaries when analysing complex texts, they have their limitations as well. The implementation of the rules is complex and time-consuming (Jiang, 2012) and requires domain-knowledge as well as programming skills (e.g., XML and CGUL) (Sarawagi, 2008). (Hagn, 2017).

[44] In the appendix, the final versions of the extraction rules are documented.

3.7.4.4 Applying Text Mining to the First Data Set

In the first iteration, the first data set of job offers was uploaded using a Python Script (cp. appendix A) and stored in the SAP HANA table "STELLENANZEIGEN"[45]. The content of the job offers was stored as Binary Large Objects (BLOB) in the column "CONTENT". As the job offers were extracted from two different online job portals, it was important to delete duplicates (Bensberg, Buscher, 2016b). The first check examined, if there were identical job offers. Therefore, the texts had to be converted into the data type BINARY, as the comparison of two BLOBs is not possible in SAP HANA. The compare statement is given in appendix D.2.1. From the first data set of 2,470 job offers (cp. section 3.7.3.2), twelve data records were marked as exact duplicates and excluded from further analysis. (Hagn, 2017).

The TA functionalities provided by SAP HANA allow the analysis of unstructured texts in different languages (SAP SE, 2017c). TA is activated during the creation of a full text index. TA in SAP HANA provides linguistic analyses, entity and fact extraction, and the analysis of grammatical roles. The functional range differs with regards to the language of the data set to be analysed (SAP SE, 2017d). For each supported language, predefined dictionaries and entities are comprised in the system. Users can add and use own dictionaries and entities (SAP SE, 2017b). (Hagn, 2017).

For being able to use the TA functionalities provided by SAP HANA, we first created a full text index on our data set. The code is shown in appendix D.2.2. As our data set comprises only German job offers, we limited the language to "DE" for German. The result table of the full text index is named "$TA_JOBADV_IDX". A detailed description of all columns can be found in SAP SE (2017b) and in Hagn (2017). This full text index can now be used for finding and flagging duplicates. The according statements are given in appendices D.2.3 and D.2.4. Regarding the 2,740 job offers from the first data set, we discovered that 180 job offers were not usable for our approach as they were stored as pictures instead of PDF or HTML file due to human failure. 210 job offers were duplicates. In our case, duplicates may result from the use of two different job portals – or from job offers that were downloaded multiple times as they lasted online longer than one month. (Hagn, 2017).

3.7.4.5 Evaluation of the Text Mining Results

A common means for rating the quality of the results of a classification is a confusion matrix. A general example is shown in Table 16. The results of a classification are checked against manually pre-classified test data sets (Feldman, Sanger, 2006; Jiang, 2012). Results classified as "true positive" and "true negative" are classified correctly. "False positives" and "false negatives" are classified wrongly. Based on the confusion matrix, the following metrics can be calculated: "precision", "recall" or "sensitivity", and "F_1-score" (Feldman, Sanger, 2006; Jiang, 2012). The calculations for these metrics are presented in formulas (1) – (3).

[45] Stellenanzeigen: Job offers. Translated by the author.

Table 16: Confusion Matrix (with regards to Witten, Frank, and Hall (2011))

		Predicted Class	
		Yes	**No**
Actual Class	**Yes**	True Positive	False Negative
	No	False Positive	True Negative

$$(1)\ precision = \frac{true\ positive}{true\ positive\ + false\ positive}$$

$$(2)\ recall = \frac{true\ positive}{true\ positive\ + false\ negative}$$

$$(3)\ F_1 - score = \frac{2}{\frac{1}{recall} + \frac{1}{precision}} = 2 \times \frac{precision\ \times recall}{precision\ + recall}$$

The metric precision is the share of relevant results among the retrieved results. The recall or sensitivity is the share of relevant results among the total results. The F_1-score represents the harmonic average of precision and recall. The best possible value for the F_1-score is 1. It is reached when precision and recall are perfect. The worst value possible is 0.

3.7.4.6 Qualitative Evaluation of the Results of our Text Mining Application

After the first analysis, we did two rounds of evaluation to determine the quality of our analysis. The first evaluation took place during the development phase on the base of fifteen manually pre-analysed job offers. The second evaluation took place after the development phase on fifty manually pre-analysed job offers. The pre-analyses were conducted be two independent researchers who had not been involved in the project so far. The manual analyses of the first test data set with fifteen job offers resulted in 239 requirements. As the analysers did not have full insight into which requirements exactly were in focus of our project (competency requirements for employees in Industry 4.0), they extracted other requirements as well, such as qualification requirements. We removed these from the result list, which then comprised 196 requirements. Our TM application extracted 126 of these competency requirements correctly (64 %). 15 (8 %) were false positives. 39 (20 %) were false negatives, and 16 (8 %) were not recognized at all. Thus, we reached a precision of 0,89 and a recall of 0,7. The F_1-score is 0,78. (Hagn, 2017).

When analysing these results, we discovered, that enumerations of nouns were not recognized so far, especially in combination with the use of hyphens – which is much more common in German language than in English. Therefore, we extended the extraction rules for these cases as documented in detail by Hagn (2017). Other competency requirements have not been recognized, e.g., due to spelling mistakes in the job offers, or when the pre-processing in SAP HANA did not recognize certain special characters. However, the main reason for unrecognized competency requirements was that corresponding patterns are missing in custom dictionaries or custom extraction rules. Thus, the effort to cover each and every possible expression of competency requirements results in a higher and higher amount of work. (Hagn, 2017).

A problem with correctly recognizing competencies appears in the field of educational background, as in the German language, it is common not to use the exact and official term of a field of study but individually extended terms (e.g., "Studium im technischen oder betriebswirtschaftlichen Bereich oder vergleichbar mit Schwerpunkt Informatik"[46]). Another problem appeared, when competency requirements were extracted from positions in the text where they were used in a different context (e.g., "Architektur" extracted from "IT-Architektur"[47]). To heal this, it could help to analyse the entities in their context, i.e., how close they are to each other (e.g., to the term "studies"). (Hagn, 2017).

After revising our TM application, we conducted a second evaluation on the second test data set of fifty pre-analysed job offers. We were able to improve the results slightly to a precision of 0,92, a recall of 0,73, and an F_1-score of 0,81. With known problems, training, and evaluation in the same domain, F_1-scores around 0,9 are not uncommon (Jiang, 2012). We did not reach this value so far due to a still high number of unrecognized competency requirements. Further improvements may be reached by extending the custom dictionaries and custom extraction rules, the transfer of the custom dictionaries into custom extraction rules, and the removal of html-tags from the texts ahead of the analysis. (Hagn, 2017). As we already were able to gain new insights from the results, we decided to go on in our research project using the results from this TM application.

3.7.4.7 Applying Text Mining to the Second Data Set

As the second data set did not comprise any duplicates, it was not needed to search for some and to flag them. Thus, we could immediately create the full text index on this data set with the same creation statement, dictionaries, and extraction rules as used for the first data set.

The results of the TM on job offers contained competencies, which have not been included in the literature- and focus group-based first version of the competency model for employees in Industry 4.0. Other competencies that were part of the first version of the model were not or hardly found in the job offers. We used the results for refining the competency model as described in section 4.3.

3.8 Curriculum Development

In this section, we descripe our approach for the curriculum development project.

3.8.1 Project Setting

This thesis is connected to the curriculum development project "The Digital Transformation of Global Bike", which was executed at SAP University Competence Center (SAP UCC) Munich (cp. section 3.8.1.1) from Q4/2015 to Q4/2017. In this project, a curriculum for teaching Industry 4.0 competencies was implemented. It builds on the case of the Digital Transformation of a

[46] Studies in a technical or economic field or comparable with focus on Informatics. Translated by the author.
[47] "Architecture" extracted from "IT architecture". Translated by the author.

virtual bicycle-selling company from a manufacturing and sales company to a product-service provider; from a traditional company to an Industry 4.0 company. The original products, traditional racing bikes, mountain bikes, and biking accessories, have been complemented by a PSS, an E-Bike which is offered to a new group of customers via bike-sharing (cp. section 5.3.2.1). The E-Bike as PSS is described in the context of the Collaborative Research Center 768[48].

The first project phase from Q4/2015 – Q2/2016 was set up as pre-project and executed by one member of the SAP UCC Munich. From Q2/2016 – Q4/2017, four members of the SAP UCC Munich executed the main part of the project. All project members were available part-time for the project due to their responsibilities for product development, maintenance and customer support in their areas in the SAP UCC Munich as well as teaching and research activities. The project team was supported from further members of SAP UCC Munich when their expertise was needed (e.g., in the area of system setup).

3.8.1.1 SAP University Alliances and the SAP University Competence Centers

The SAP University Competence Center (SAP UCC) Munich is an Education as a Service (EaaS) provider, located at the chair for Information Systems of Prof. Dr. Helmut Krcmar at the Technical University of Munich (TUM) in Garching bei München, Germany. Together with five other SAP UCCs located all around the world, the SAP UCC Munich is part of the SAP University Alliances (SAP UA) programme. "SAP [UA] is a global program [sic!] enabling more than 3,500 educational institutions in over 113 countries to integrate the latest SAP technologies into teaching" (SAP SE, 2018d). Along with the SAP UCC at the Otto-von-Guericke-Universität (OVGU) in Magdeburg, Germany, the SAP UCC Munich is responsible for the EMEA region. The SAP UCCs host SAP software solutions such as SAP ERP, SAP Business Warehouse (SAP BW), SAP Business Warehouse for HANA (SAP BW/4HANA), SAP HANA, and SAP Business Suite for HANA (SAP S/4HANA). Educational and research institutions that are member of the SAP UA programme can get access to the SAP applications for teaching and research. Besides hosting systems, the SAP UCCs develop and maintain teaching materials for universities and other institutions of (higher) eduction – "curricula" – such as slides, readers, hands-on exercises, hands-on case studies and hands-on challenges as well as customer support for the systems and curricula provided. (Prifti, Knigge, Löffler, et al., 2017).[49]

The curriculum development project "The Digital Transformation of Global Bike" was located at the SAP UCC Munich. This SAP UCC builds on more than fifteen years of developing, providing, and maintaining learning materials based on different SAP applications and on different levels of technical detail. In this environment, we were able to use and try out the latest SAP technologies, such as SAP HANA (cp. section 3.8.3.1) and SAP S/4HANA (cp. section 3.8.3.2), and to create hands-on exercises and demonstration based on those. Furthermore, we

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[48] CRC 768/SFB 768: Collaborative Research Center (CRC) 768: Managing Cycles in Innovation Processes – Integrated Development of Product-Service Systems Based on Technical Products. http://www.sfb768.tum.de/en/home/. Sonderforschungsbereich (SFB) 768: Zyklenmanagement von Innovationsprozessen – verzahnte Entwicklung von Leistungsbündeln auf Basis technischer Produkte. http://www.sfb768.tum.de/startseite/.

[49] For more information regarding the SAP UCCs EMEA (Munich and Magdeburg), please cp. www.sap-ucc.com. Accessed on May 22nd, 2018.

were able to build on and learn from a customer base, which consist of lecturers and teachers in several hundred universities and other institutions of (higher) education, who are using the SAP UCC services. Over the past fifteen years, the curriculum materials developed in the SAP UCCs have reached a certain quality standard and stage of maturation due to the experiences gathered while developing, applying, and maintaining them.

3.8.1.2 The Global Bike Teaching and Learning Environment

In the context of SAP UA, the SAP UCCs provide the "Global Bike Teaching and Learning Environment". The curriculum "The Digital Transformation of Global Bike" builds on this environment. It comprises the ""Global Bike" model enterprise" (SAP UCC Magdeburg, SAP UCC Munich, 2018b), a virtual company for training issues which produces and sells bicycles and related accessories. Besides, it includes "[v]arious SAP solutions (SAP system landscape)" (SAP UCC Magdeburg, SAP UCC Munich, 2018b) that can be accessed for teaching in the context of SAP UA by the SAP UCCs' customers. This offering is complemented by the third brick, "[t]eaching material for different learning types, learning objectives[,] and teaching methods" (SAP UCC Magdeburg, SAP UCC Munich, 2018b), which include presentation slides, hands-on exercises and corresponding sample solutions, case studies, lecturer notes, etc. (cp. SAP UCC Magdeburg, SAP UCC Munich, 2018b). Global Bike is available in German and English language (cp. SAP UCC Magdeburg, SAP UCC Munich, 2018b).

A data set that represents the virtual company Global Bike is available for being used in the following SAP applications:

- SAP ERP
- SAP S/4 HANA
- SAP BW
- SAP HANA
- SAP Lumira
- SAP CRM (Customer Relationship Management)
- SAP SCM (Supply Chain Management)

Customers of the SAP UCCs can use the corresponding exercises and case studies (cp. SAP UCC Magdeburg, SAP UCC Munich, 2018b). To illustrate the coverage of the Global Bike dataset, the areas of SAP ERP for which exercises and case studies are available are given here:

- Procurement (SAP module Materials Management (MM))
- Manufacturing (SAP module Production Planning (PP))
- Sales (SAP module Sales and Distribution (SD))
- Financial accounting (SAP module Financial Accounting (FI))
- Managerial accounting (SAP module Controlling (CO))
- Human capital management (SAP module Human Capital Management (HCM))
- Warehouse management (SAP module Warehouse Management (WM))
- Maintenance (SAP module Enterprise Asset Management (EAM))
- Project management (SAP module Project System (PS))

- Customer service (SAP modules Customer Service (CS) and/or Customer Relationship Management (CRM))
- Quality management (SAP module Quality Management (QM))
  (SAP UCC Magdeburg, 2017; SAP UCC Magdeburg, SAP UCC Munich, 2018b)

3.8.1.3 Overview of the Virtual Company "Global Bike"

In this section, we give a short overview of the story of the virtual company "Global Bike". John Davis, who had a company for racing bicycles in the US, and Peter Schwarz, who had a company for touring bicycles in Germany, founded the virtual company "Global Bike Group". They merged their companies to form "Global Bike Inc." (GBI). Both act as Co-Chief Execution Officers (CEOs) of the now multinational company. Its organizational structure is represented in the SAP ERP-system. For each company, plant and department, the staff responsible is implemented in the SAP ERP-system as well. The former US company lead by John Davis and the former German company lead by Peter Schwarz both comprise several plants and locations. While the German branch focusses on the idea-to-market (research, design) and the build-to-stock (procurement, manufacturing) processes, the US branch is responsible for the order-to-cash (sales, marketing) process as well as for customer service and support and support processes for the four main business processes mentioned beforehand, such as IT, finance, and HR. (Cp. Magal, Weidner, Word, 2017).

Global Bike produces and sells touring and off-road bicycles from raw materials and semi-finished goods. Moreover, the company buys and sells accessories such as air pumps, elbow pads, or first aid kits. (Magal et al., 2017). All marterials, suppliers, and customers are already maintained in the SAP ERP-system. The materials available comprise raw materials, trading, semi-finished and finished goods (products). All information needed for producing bicycles from the raw materials such as bill of materials (BOMs), workplaces, and routeings are maintained in the system as well. The customers of Global Bike are bicycle shops, not end customers.

Data for all those entities is provided in the SAP ERP-systems offered by the SAP UCCs. This enables lecturers and students to execute processes without having to prepare the data that is needed in a process beforehand. The Global Bike story and data can be extended in consultation with the SAP UCCs (SAP UCC Magdeburg, SAP UCC Munich, 2018a).

3.8.2 Project Target

The project target was to develop an Industry 4.0 curriculum for higher education in the context of the SAP UCCs and their software and learning environment.

3.8.2.1 Target: Industry 4.0 curriculum and target group

Before involving the potential customers, we started with outlining a first idea: to implement a curriculum that deals with the challenges of the Fourth Industrial Revolution and its implications on work and the working environments. In our project environment, we had the possibility to integrate SAP SE's latest solutions for demonstrations and hands-on exercises. In addition, we defined a target group that we had access to via the SAP UCCs and SAP UA: Teachers, lecturer, and the corresponding learning audience in (higher) education from the fields of Economics, IS, Computer Sciences, and Engineering.

3.8.2.2 Project Organization and Time Frame

The project for the implementation of the curriculum "The Digital Transformation of Global Bike" started in October 2015 as pre-study. From June 2016 on, the core project team took over. Other team members of the SAP UCC Munich supported the project if needed. The curriculum development project was divided into three sub-projects. Figure 15, Figure 16, and Figure 17 illustrate which sub-project was responsible for providing which content. Since the structure of the curriculum was developed over time, the responsibilities of the sub-projects were adjusted

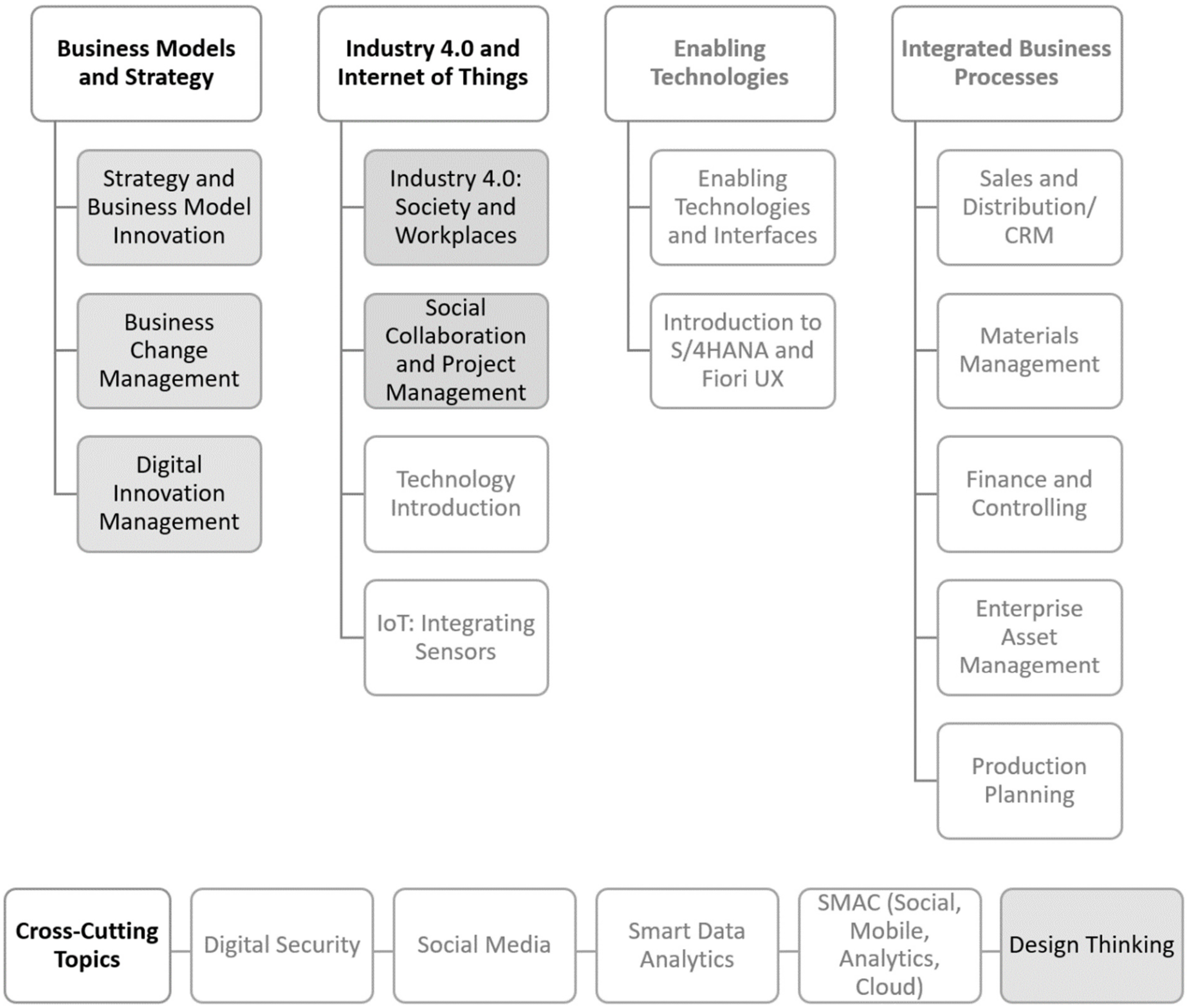

Figure 15: Curriculum Modules under the Responsibility of Sub-Project 1 (with regards to Knigge (2016))

if needed as well.

For illustrating the responsibilities, we refer to the final structure of the first release of the curriculum. Sub-project 1 is described in detail by Prifti (2019). Besides the responsibility for the modules shown in Figure 15, it comprised the responsibility for the implementation of the "Course Calculator" (cp. section 5.7.5) as well as the "Test Your Knowledge" slides and the

“Discussion Slides”. Further team members of the SAP UCC Munich were responsible for the implementation of the modules assigned to sub-project 2 (cp. Figure 16).

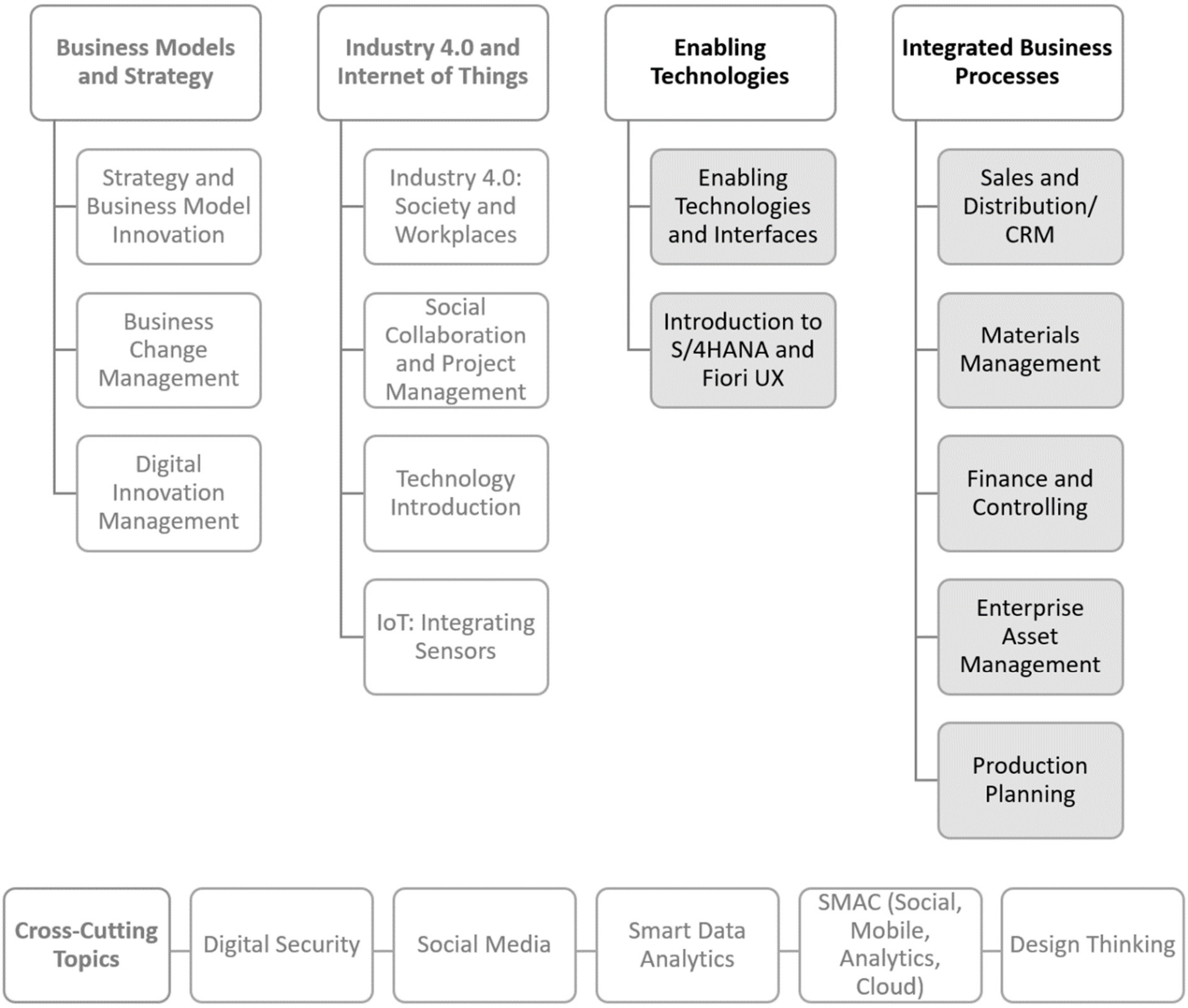

Figure 16: Curriculum Modules under the Responsibility of Sub-Project 2 (with regards to Knigge (2016))

Sub-project 3 (cp. Figure 17) was under the responsibility of the author of this thesis. In addition to the responsibility of the modules shown in Figure 17, it was part of sub-project 3 to implement the curriculum navigation application (cp. section 5.4). to integrate interactive elements such as OnlineTED (cp. section 5.7.3) and Answer Garden (cp. section 5.7.4) as well as to implement the glossary (cp. section 5.7.6) and the list of abbreviations (cp. section 5.7.7).

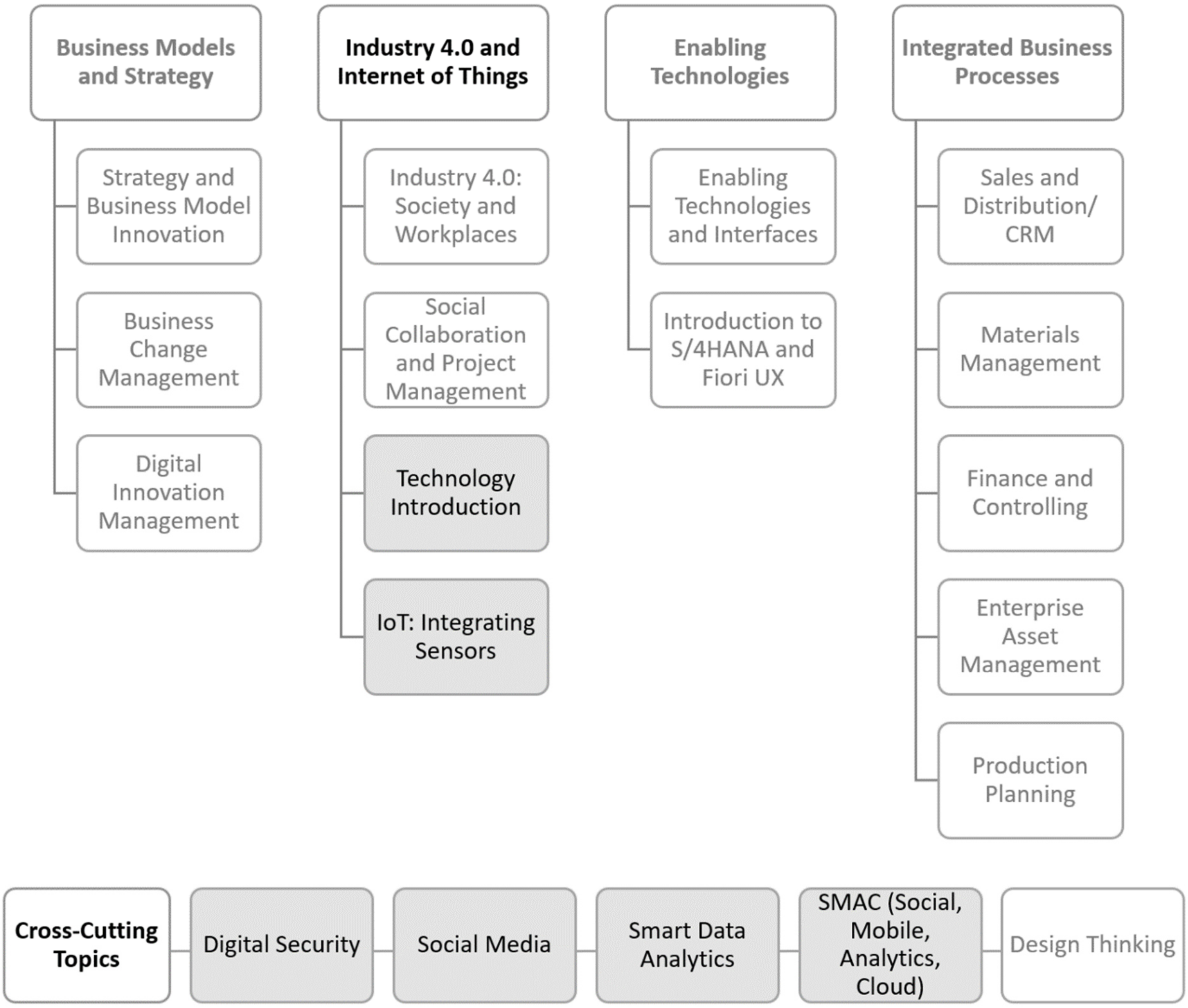

Figure 17: Curriculum Modules under the Responsibility of Sub-Project 3 (with regards to Knigge (2016))

Each sub-project was responsible for implementing the content for its modules, including the organization the review of the content that had to be done by members of the other sub-projects, and to revise the content after the review.

The first milestone of the curriculum development project was to present a first draft of the upcoming curriculum at the SAP UA Academic Conference EMEA 2016 in Potsdam, Germany. There, a flyer with the first draft of the curriculum structure and some additional information were presented (Knigge, 2016). The final goal for the curriculum development project was to launch the first release – after a pilot phase – at the SAP UC Academic Conference EMEA 2017 in Karlsruhe, Germany. The project – and later the sub-projects – reported to the principal of the project, Prof. Krcmar, on a monthly base. Project meetings were conducted on a weekly or bi-weekly base – depending on the needs of the project members.

3.8.3 Technical Setting

As part of their offerings, the SAP UCCs provide new teaching materials based on traditional, and especially emerging SAP applications. SAP S/4HANA, which is available since 2015, is the successor of SAP SE's ERP system (cp. section 3.8.3.2). It is influenced by digitization and ready to support companies in Industry 4.0 (Vetter, 2016). SAP HANA is not only the DB that SAP S/4HANA builds on. It is a modern in-memory DB that offers means and add-ons for smart data analytics. It can also be used as stand-alone DB in other contexts – especially for analytical applications (cp. section 3.8.3.1). Having this setting available, it suggests itself to use SAP HANA and SAP S/4HANA as platforms for the implementation of an Industry 4.0 curriculum.

3.8.3.1 SAP HANA

SAP HANA has been developed by SAP SE, the HPI, and Stanford University for the purpose of real-time analysis of big data. It has been introduced in 2008 and is available since 2010. It is an in-memory DB and application development platform at the same time. For this combination, SAP SE uses the term "appliance". It comprises a DB, functions for analytics processing, app development, data access, administration, security, flexible deployment options, and is open to other formats and standards. SAP HANA is available as cloud, on-premise, or hybrid solution and can be used as "[s]ecure, future-ready in-memory data platform" (SAP SE, 2018a) and for "[l]ive intelligence with fast data processing" (SAP SE, 2018a). (SAP SE, 2018a). SAP HANA is suited to execute both, Online Transactional Processing (OLTP) and Online Analytical Processing (OLAP) transactions (cp. section 2.1). (SAP SE, 2018a). Therefore, it offers column-based and row-based storage of data. While the classical row-based storage is better suited for transactional processing, the column-based storages enables very fast aggregations and therefore fast analytical processing.

As SAP SE wants to profit from the benefits of this new in-memory DB, it started using SAP HANA as DB for its classical applications SAP ERP/Business Suite and SAP SAP BW. In the next step, SAP SE started to transfer calculation routines from the application servers of SAP ERP and SAP BW to the underlying SAP HANA ("code pushdown"), which resulted in a huge decrease of calculating time of the applications. These new, Industry 4.0-ready applications are SAP S/4HANA (cp. section 3.8.3.2), introduced in 2015, and SAP BW/4HANA, introduced in 2016. SAP HANA updates are released as Support Pack Stacks (SPS) that can be added to the system (SAP SE, 2018b). Since SAP HANA is a quite new, complex, and innovative product, the changes from one SPS to the next can be significant. Besides bug fixing, functionality can be added, removed, or changed from one SPS to the next. Since 2016, SAP HANA 2.0 is available.

3.8.3.2 SAP S/4HANA with SAP Fiori UX

SAP SE (2018c) entitles SAP S/4HANA as "[t]he next-generation ERP business suite" (SAP SE, 2018c). SAP S/4 HANA does not only consume SAP HANA as DB but calculation routines were moved from the ERP application server to SAP HANA, so SAP S/4HANA can entirely benefit from the performance improvements the in-memory database SAP HANA offers. Thus, SAP S/4HANA offers "a digital core to connect […] [an] enterprise with people, business networks, the Internet of Things, Big Data, and more" (SAP SE, 2018c). It is available as cloud, on-premise, or hybrid solution and offers "[a]rtificial intelligence capabilities" (SAP SE, 2018c) and "[n]ext generation processes" (SAP SE, 2018c).

Besides much faster computation due to the use of SAP HANA as foundation and a new, optimized data model, SAP S/4HANA comes with a new, modern, intuitive graphical user interface (GUI), which is called SAP Fiori UX (User Experience). The SAP GUI for Windows was available since the beginning of the 1990s. There have been several updates and patches since then. However, nowadays it looks old-fashioned and is not comfortable to use anymore as it has some limitations, which originate in times when storage and computing time have been expensive. With SAP Fiori UX, SAP offers a modern user interface for large parts of SAP S/4HANA, which is reduced and much more intuitive – and therefore easier to use. The SAP Fiori UX is based on OData, SAPUI5 (SAP User Interface 5), and the SAP Web IDE (Integrated Development Environment). The administration is done with the SAP Fiori Launchpad. SAP Fiori was introduced in 2013, SAP Fiori 2.0 in 2015.

3.8.3.3 Curriculum Navigation Application

To give a comprehensive description of the system architecture of our prototype Industry 4.0 curriculum, we have to anticipate at this point some details about the structure of the curriculum. After it was clear that our curriculum would contain a large number of different materials, we had to decide about how to structure and present the materials. Simply arranging the materials in folders and then offer them as compressed file, e.g., as ZIP file, to our customers seemed not to be an optimal solution as it would be difficult to find single materials or to follow our predefined paths through the curriculum (cp. sections 5.3 and 5.5). Therefore, we decided to implement a lightweight application to structure our materials and to guide users with special interests through the materials. On the one hand, we used a modular structure to cluster the materials concerning topics, on the other hand we defined learning journeys that combined materials from different topics – and therefore, from different modules – to create a comprehensive story. (cp. sections 5.3 and 5.5). The main requirement for distributing the curriculum to the SAP UCCs' customers is that it should be possible for customers to download the whole curriculum to their local clients. It should be possible to use it without having to install another application. It is important, that materials such as slides can be used on the client without any internet connections – for lecturers who want to prepare the next session as well as for students who want to learn for an exam.

Therefore, we decided to create a simple HTML application. To run it, the customer does not need more than a current browser, such as Google Chrome, Mozilla Firefox, or Microsoft Edge. The curriculum navigation application is described in detail in section 5.4.

In the next chapter, we will answer RQ1 by describing and refining the comprehensive competency model for employees in Industry 4.0.

4 Skill and Competency Requirements for Industry 4.0 Employees

We already discussed the significant changes Industry 4.0 will bring to workplaces and job profiles (e.g., cp. sections 1.1, 2.2, 2.3, and 2.4), and that there will be an increase of jobs that require employees with a higher qualification (cp. section 1.1). “[V]arious practitioners and researchers agree that […] competency developments for students and employees applying for jobs that require higher education is one of the key challenges to adapt I[ndustry]4.0” (Prifti, Knigge, Kienegger, et al. (2017a, p. 47) with regards to Zinn (2015), Richter et al. (2015), Jaschke (2014), Erol et al. (2016), Wee, Kelly, Cattel, and Breunig (2015), Making in an Industry 4.0 World (2015), and Lorenz et al. (2015)). Prifti, Knigge, Kienegger, et al. (2017a) emphasize, that “[i]n order to successfully get through the [digital] transformation towards I[ndustry]4.0, a clear definition of the competencies for I[ndustry]4.0 is needed” (Prifti, Knigge, Kienegger, et al. (2017a, p. 47) with regards to Richter et al. (2015), Jaschke (2014), and Richert et al. (2016)). In order to address this need, this section deals with answering the following research question:

RQ1: Which skills and competencies do employees need for working in an Industry 4.0 environment?

Using different sources of information such as scientific literature, focus group interviews with participants from academia, and job offers, skills and competency requirements for Industry 4.0 employees are derived, analysed, and clustered. As result, a competency model for Industry 4.0 employees is presented.

In a first iteration, a first competency model for employees in Industry 4.0 is derived from literature and focus group interviews with participants from academia (cp. section 4.1). In a second iteration, this Industry 4.0-specifc competency model is supplemented with general competencies (cp. section model 4.2). In a third iteration, the resulting combined competency model is validated and supplemented with results from TM on job offers (cp. sections 4.3).

4.1 Skill and Competency Requirements for Industry 4.0 employees from Literature and Focus Group Interviews

In the first phase of the development of a competency model for Industry 4.0 employees, we analysed scientific and practitioners’ publications and conducted focus group interviews with European professional lecturers from institutions of – mainly higher – education. The result is a first competency model for Industry 4.0 employees that was published by Prifti, Knigge, Kienegger, et al. (2017a) and Prifti, Knigge, Kienegger, et al. (2017b) in 2017. In this section, we will only present the results of these papers in short.

Prifti, Knigge, Kienegger, et al. (2017a) define the target groups for their competency model for employees in Industry 4.0 as follows:

"I[ndustry]4.0 is accompanied by the enhancement of production machines, which requires adjusted competency profiles for engineers. IT assumes the role of programming these machines and designing adjusted IT architectures, which requires new competencies for IT professionals. These changes in production, the transformation of business processes as well as new ways of communication and collaboration 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 […] [.]IS[.] professionals. Job profiles for engineering, IT, and IS employees need to be adjusted and include new competencies in order to cope with I[ndustry]4.0." (Prifti, Knigge, Kienegger, et al., 2017a, p. 47).

Thus, the target groups of the first version of the competency model for employees in Industry 4.0 are students and employees working in the areas of engineering, IT, and IS.

4.1.1 Skill and Competency Requirements from Literature

From the literature on scientific and practitioners' literature which is described in section 3.4 as well as by Prifti, Knigge, Kienegger, et al. (2017a) and Prifti, Knigge, Kienegger, et al. (2017b), we derived 64 competencies required by employees in Industry 4.0. The majority are behavioural competencies, which "underlines the importance of behavioral [sic!] competencies for I[ndustry] 4.0" (Prifti, Knigge, Kienegger, et al., 2017a, p. 53). The competencies are listed in Table 17.

Table 17: Competencies for Employees in Industry 4.0 from Literature

Competencies	Mentioned by
Communication	– Kagermann et al. (2013) – Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Smit et al. (2016) – Richter et al. (2015) – Erol et al. (2016) – Guo (2015) – Gehrke et al. (2015) – Kiesel and Wolpers (2015) – Xia (2011) – Grega and Kornecki (2015) – Grimheden and Törngren (2014) – Mäenpää et al. (2015)
Literacy	– Xia (2011)
Technical communication	– Erol et al. (2016) – Xia (2011)
Intercultural/cross-cultural	– Erol et al. (2016) – Gehrke et al. (2015) – Xia (2011)
Presentation	– Blanchet et al. (2014)
Collaboration	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016)

Competencies	Mentioned by
	– Richter et al. (2015) – Kiesel and Wolpers (2015) – Blanchet et al. (2014) – Gray (2016)
Compromising	– Erol et al. (2016)
Negotiating	– Gray (2016)
Emotional intelligence	– Gray (2016)
Teamwork	– Richter et al. (2015) – Erol et al. (2016) – Gehrke et al. (2015) – Kiesel and Wolpers (2015) – Grega and Kornecki (2015)
Project management	– Grimheden and Törngren (2014) – Mäenpää et al. (2015)
Management	– Smit et al. (2016)
Customer orientation	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Gehrke et al. (2015)
Customer relations	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Hoberg et al. (2017)
Business networks	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Hoberg et al. (2017)
Problem solving	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Gebhardt et al. (2015) – Smit et al. (2016) – Richter et al. (2015) – Erol et al. (2016) – Windelband (2014) – Kiesel and Wolpers (2015) – Gray (2016)
Optimization	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Gebhardt et al. (2015)
Analytical skills	– Erol et al. (2016) – Lorenz et al. (2015) – Hartmann and Bovenschulte (2013)
Cognitive abilities	– Gray (2016)
Management of complexity	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Erol et al. (2016)
Abstraction ability	– Smit et al. (2016) – Erol et al. (2016) – Windelband (2014)
Decision making	– Kagermann et al. (2013) – Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016)

Competencies	Mentioned by
	– Smit et al. (2016) – Gray (2016) – Kortuem et al. (2013)
Taking responsibility	– Smit et al. (2016)
Leadership	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Smit et al. (2016) – Lorenz et al. (2015) – Gray (2016)
Ethics	– Grega and Kornecki (2015)
Environmental awareness	– Grimheden and Törngren (2014) – Mäenpää et al. (2015)
Awareness for ergonomics	– Gehrke et al. (2015)
Working in interdisciplinary environments	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Gebhardt et al. (2015) – Richter et al. (2015) – Lorenz et al. (2015) – Gehrke et al. (2015) – Grega and Kornecki (2015) – Blanchet et al. (2014)
Flexibility	– Erol et al. (2016)
Adaptability	– Gehrke et al. (2015) – Kiesel and Wolpers (2015)
Innovation skills	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Stocker et al. (2014)
Creativity	– Richter et al. (2015) – Erol et al. (2016) – Stocker et al. (2014) – Kiesel and Wolpers (2015)
Critical thinking	– Kiesel and Wolpers (2015)
Change management	– Hoberg et al. (2017)
Life-long learning	– Gebhardt et al. (2015) – Erol et al. (2016) – Lorenz et al. (2015) – Kiesel and Wolpers (2015) – Xia (2011) – Grega and Kornecki (2015) – Blanchet et al. (2014)
Knowledge management	– Gehrke et al. (2015) – Kiesel and Wolpers (2015)
Business strategy	– Zinn (2015)
Business models	– Zinn (2015) – Blanchet et al. (2014)

Competencies	Mentioned by
Entrepreneurship	– Kiesel and Wolpers (2015)
Work-life balance	– Erol et al. (2016)
Self-management and -organization	– Kagermann et al. (2013) – Smit et al. (2016) – Gehrke et al. (2015) – Kiesel and Wolpers (2015)
Planning and organizing work	– Gehrke et al. (2015) – Kiesel and Wolpers (2015) – Hartmann and Bovenschulte (2013)
Legislation	– Gehrke et al. (2015) – Grimheden and Törngren (2014) – Mäenpää et al. (2015)
Safety awareness	– Grega and Kornecki (2015) – Hartmann and Bovenschulte (2013)
Individual responsibility	– Smit et al. (2016)
IT and technology	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Gebhardt et al. (2015) – Erol et al. (2016) – Lorenz et al. (2015) – Guo (2015) – Gehrke et al. (2015) – Hoberg et al. (2017) – Hartmann and Bovenschulte (2013)
Economics	– Grimheden and Törngren (2014) – Mäenpää et al. (2015)
Extract business value from social media	– Erol et al. (2016) – Hoberg et al. (2017)
Servia orientation, product service offerings	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Zinn (2015) – Hoberg et al. (2017) – Chunzhi et al. (2012)
Business processes	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Zinn (2015) – Erol et al. (2016) – Gehrke et al. (2015) – Blanchet et al. (2014)
Digital security	– Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) – Zinn (2015) – Grega and Kornecki (2015) – Hoberg et al. (2017) – Chunzhi et al. (2012)

Competencies	Mentioned by
Integrating heterogeneous technologies	− Grega and Kornecki (2015) − Grimheden and Törngren (2014) − Mäenpää et al. (2015)
Mobile technologies	− Hoberg et al. (2017)
Embedded systems, sensors	− Grega and Kornecki (2015)
Network technology, M2M[50] communication	− Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) − Zinn (2015) − Gebhardt et al. (2015) − Erol et al. (2016) − Blanchet et al. (2014) − Chunzhi et al. (2012)
Robotics, artificial intelligence (AI)	− Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) − Lorenz et al. (2015) − Hartmann and Bovenschulte (2013)
Modelling and programming	− Erol et al. (2016) − Lorenz et al. (2015) − Gehrke et al. (2015) − Kortuem et al. (2013) − Chin and Callaghan (2013)
Cloud computing and architectures	− Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) − Hoberg et al. (2017) − Chunzhi et al. (2012)
In-memory DBs	− Hoberg et al. (2017)
Statistics	− Gehrke et al. (2015)
Big data analysis and interpretation	− Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) − Zinn (2015) − Erol et al. (2016) − Lorenz et al. (2015) − Gehrke et al. (2015) − Blanchet et al. (2014) − Hoberg et al. (2017) − Bechtold et al. (2015)

Together with the results from the focus group interviews, which are presented in section 4.1.2, these competencies build the first part of the foundation of the first version of our competency model for employees in Industry 4.0 which is presented in section 4.1.3 and published by Prifti, Knigge, Kienegger, et al. (2017a) and Prifti, Knigge, Kienegger, et al. (2017b).

[50] M2M: Machine-to-machine.

4.1.2 *Skill and Competency Requirements from Focus Group Interviews with Personnel from Academia*

The participants of the focus group interviews were teaching staff from institutions of (higher) education from the areas of IT, IS, Economics, and Engineering (cp. section 3.5). As it corresponds with their teaching subjects, it is not a surprise that the competency mostly mentioned by them was big data/data analytics. One participant stated: *"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."* (Prifti, Knigge, Kienegger, et al., 2017a, p. 54). *"The participants see […] [big data/data analytics] as the next big thing and believe that for succeeding in I[ndustry] 4.0, a combination of big data competency with sensor[.] and mobile technology as well as predictive maintenance and machine learning will be very important"* (Prifti, Knigge, Kienegger, et al., 2017a, p. 54).

In total, we extracted the following competencies for employees in Industry 4.0 from the focus group interviews (cp. Prifti, Knigge, Kienegger, et al. (2017a)):

- Big data/data analytics (incl. geo data, videos, images, ERP data, structured data, unstructured data, data from social media, volume data, data traffic)
- Sensor technology
- Mobile technology
- Predictive maintenance
- Machine learning
- Process know-how
- Process management
- Automation, automated processes
- Business models
- Entrepreneurship
- Identify and make use of technological advances
- Adapt in a fastly changing world
- Multidisciplinary, interdisciplinary
- Collaboration
- Technology
- Network administration
- Data security
- Cloud architectures
- Programming
- In-memory DBs
- Customer orientation
- Decision making
- Communication
- Innovation
- Legal
- Ethics

- Teamwork/group work

Together with the results from the literature review, these competencies build the first part of the foundation of the competency model for employees in Industry 4.0.

4.1.3 A Competency Model for Employees in Industry 4.0

As described in 2.6.3, we decided to build our competency model for employees in Industry 4.0 on the SHL UCF proposed by Bartram (2005). We use the “Great Eight” and the “Competency Dimensions” from Bartram (2005), as presented in Table 3 and Table 4. We arranged the 64 competencies for employees in Industry 4.0 found in the literature review on the third level – “Competencies”. We then checked the competencies identified in the focus group interviews against these and added four more competencies: “Customer Relationship Management”, “IT architectures”, “Machine Learning”, and “Predictive Maintenance” (Prifti, Knigge, Kienegger, et al., 2017a, p. 54 f.). Thus, in total, we ended up with 68 competencies in the first version of our competency model for employees in Industry 4.0, which is presented in Table 18. It should be noted that we found no competencies from the areas of leadership and persuading and influencing in the transcripts of our focus group interviews. The level of detail in describing the competencies was much higher in the literature than in the transcripts of the focus group interviews. (Prifti, Knigge, Kienegger, et al., 2017a).

While building the competency model for employees in Industry 4.0, two researches decided independently for each of the 68 competencies for which of the following fields it was relevant: IS, IT, Engineering – or for two or even all three of those fields. We compared and discussed the results. The assignment of the competencies to the three fields is implemented with three columns in the model – one for each field (cp. Table 18). It is obvious, that only competencies in the dimension “Applying Expertise and Technology” are divided corresponding to the three fields; this dimension contains the domain knowledge. All other competencies, of which the majority are behavioural competencies, are becoming more and more relevant for employees in all areas. The result – the first version of our competency model for employees in Industry 4.0 – was published by Prifti, Knigge, Kienegger, et al. (2017a) and Prifti, Knigge, Kienegger, et al. (2017b).

Table 18: A Competency Model for Employees in Industry 4.0 (with regards to Prifti, Knigge, Kienegger, et al. (2017a, p. 56 f.) and Bartram (2005, p. 1202 f.))

Great Eight	Competency Dimensions	Competencies		
		Information Systems (IS), Economics	**Computer Sciences**	**Engineering**
Leading and Decid-	Deciding and Initiating Action	• Decision Making • Taking Responsibility		
	Leading and Supervising	• Leadership Skills		
Supporting and Cooperating	Working with People	• Teamwork • Collaborating with Others • Communicating with People		
	Adhering to Principles and Values	• Respecting Ethics • Environmental Awareness • Awareness for Ergonomics		
Interacting and Presenting	Relating and Networking	• Compromising • Creating Business Networks • Maintaining Customer Relationships		
	Persuading and Influencing	• Negotiating • Emotional Intelligence		
	Presenting and Communicating Information	• Presentation and Communication Ability		
	Writing and Reporting	• Targeted/Technical Communication • Literacy		
Analyzing and Interpreting	Applying Expertise and Technology	• IT and Technology Affinity • Economics • Extract Business Value from Social Media		
		• Service Orientation/ Product Service Offering • Business Process Management (BPM) • Business Change Management • Understand and Co-ordinate Workflows	• Network Security • IT Architectures • Machine Learning	
			• System Development • Integrating Heterogeneous Technologies • Mobile Technologies • Sensors/Embedded Systems • Network Technology/M2M Communication • Robotics/Artificial Intelligence • Predictive Maintenance	
		• Modelling and Programming • Big Data/Data Analysis and Interpretation • Cloud Computing/Architectures • In-Memory DBs • Statistics • Data Security		
	Analyzing	• Problem Solving • Optimization		

Great Eight	Competency Dimensions	Competencies
Creating and Conceptualizing		• Analytical Skills • Cognitive Ability
	Learning and Researching	• Life-Long Learning • Knowledge Management
	Creating and Innovating	• Innovating • Creativity • Critical Thinking • Change Management
	Formulating Strategies and Concepts	• Business Strategy • Abstraction Ability • Managing Complexity
Organizing and Executing	Planning and Organizing	• Project Management • Planning and Organizing Work • Management Ability
	Delivering Results and Meeting Customer Expectations	• Customer Orientation • Customer Relationship Management (CRM)
	Following Instructions and Procedures	• Legislation Awareness • Safety Awareness • Individual Responsibility
Adapting and Coping	Adapting and Responding to Change	• Work in Interdisciplinary Environments • Intercultural Competency • Flexibility • Adaptability and Ability to Change Mind-Sets
	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

Regarding this first version of our competency model, we concluded that most of the competencies are no "new" competencies (except domain knowledge regarding new technologies). However, the combination, the weighting and the expectation of how much of these competencies an employee should fulfil to what degree are new. We see that behavioural competencies become more important in comparison to domain related knowledge.

4.2 A Combined Competency Model for Employees in Industry 4.0 Including General and Industry 4.0-Specific Competencies

After we published our first, Industry 4.0-specific version of a competency model for employees in Industry 4.0 in Prifti, Knigge, Kienegger, et al. (2017a) and Prifti, Knigge, Kienegger, et al. (2017b), we wanted to add the corresponding general competencies. In the scope of this revision, we conducted a second literature review on competency models and frameworks in order to improve our model with the findings. The methodology of this literature review is described in section 3.6, the results of the literature review are discussed in section 4.2.1 and in Hagn (2017).

4.2.1 Results from the Literature Review on Competency Models and Frameworks

We conducted the literature review on competency models as described in section 3.6 and by Hagn (2017). During our analysis of the results of the literature review on competency models presented in Table 13, we excluded competency models that focussed on specific industrial sectors or on jobs that are not related to Industry 4.0 – as they do not contain Industry 4.0-specific or general competencies. Three articles name competencies for Industry 4.0: Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016), Erol et al. (2016), and Gehrke et al. (2015). Prifti, Knigge, Kienegger, et al. (2017a) and Prifti, Knigge, Kienegger, et al. (2017b) aggregate competencies relevant for employees in Industry 4.0 into a competency model. Most of the competencies in the model are soft skills, social competencies, and general IT competencies, which is in line with Pfeiffer (2015). Only few competencies are new, most of the competencies mentioned have been part of education for years, e.g., in mechanical and electric engineering (Ahrens, Spöttl, 2015). (Hagn, 2017).

4.2.1.1 Dimensions of Competency Models

Competency models can be divided in three dimensions: the kind of competencies comprised, the application area of the competencies, and the hierarchical classification (cp. section 2.6.3). In the following, we will discuss the specific needs for each dimension of a compentency model for Industry 4.0.

The first dimension deals with what kind of competencies shall be comprised in the competency model. For a competency model for employees in Industry 4.0, both kinds of competencies are needed, specific ones and general ones. The model needs to comprise competencies that emerge in the scope of the Digital Transformation as well as already known competencies which gain more importance than before. There is no “ideal number” of competencies that should be comprised in a model (Campion et al., 2011). However, a competency model typically compasses ten to forty competencies (Erpenbeck et al., 2013), but is not limited to this. As Industry 4.0 is a wide field, our competency may comprise more than forty competences. Depending on employers, different subsets of competencies may be required from applicants (Suleman, 2016). There is consensus only regarding interpersonal skills such as communication and teamwork abilities. Suleman (2016) assumes, that analytical skills and the ability to identify and select data is always needed as well – even if not mentioned. Both statements are supported by a survey with 2,000 German companies, conducted in 2015 (Kompetent und Praxisnah, 2015). In total, the competency model for employees in Industry 4.0 needs to comprise both, general as well as Industry 4.0 competencies. (Hagn, 2017).

The second dimension deals with the application area of the competency model. We analysed online job offers without looking at a specific job or industrial sectors as our goal is to develop a comprehensive competency model – and not one specialized on a certain industrial sector or management level. Such a universal applicability does not require all competencies to be explicitly named in the model. Especially with domain specific competencies, this would almost be impossible. It is an approved approach to capture domain specific competencies in a separate category in a competency model (cp. our first version of the competency model for employees in Industry 4.0, presented in section 4.1.3 and published in Prifti, Knigge, Kienegger, et al. (2017a) and Prifti, Knigge, Kienegger, et al. (2017b); and Erpenbeck et al. (2013)). (Hagn, 2017).

The third dimension deals with the hierarchical arrangement of the competencies. There exist competency models without any hierarchies (e.g., Zhang, Wang, and Li (2010)). May and Ossenberg (2014) see a strong demand to cluster competencies. Most competency models comprise such clusters – however, these clusters may differ from model to model. May and Ossenberg (2014) point out, that there are mostly two types of clusters: one for individual competencies and the competencies needed to interact with others, and one for domain specific competencies. (Hagn, 2017).

4.2.1.2 An Overview of Existing Competency Models

The competency models identified in the literature review (cp. section 3.6 and Hagn (2017)) built on collections of competencies from different sources:

- Scientific sources and already existing models (Armstrong and Henry (2009), Lee (2010), McPherson et al. (2016), Salleh et al. (2015), Prifti, Knigge, Kienegger, et al. (2017a), and Wiratmadja et al. (2014))
- Guidelines (Armstrong and Henry (2009))
- Training programs (Cerinšek and Dolinšek (2011))
- Job descriptions (Cerinšek and Dolinšek (2011))
- Surveys (Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016), Camuffo and Comacchio (2005), Lans et al. (2014), and Yadav and Nalawade (2012))
- Expert interviews (Camuffo and Comacchio (2005), Cerinšek and Dolinšek (2011), and Spencer and Spencer (1993))
- Focus groups (Lans et al. (2014) and Prifti, Knigge, Kienegger, et al. (2017a))
(Hagn, 2017).

Moreover, the competency models differ in the amounts of competencies contained. While the leadership model presented by Jin et al. (2006) contains only three competencies, the general competency model presented in the Handbuch Kompetenzmessung (2007) contains 64 competencies. General competency models tend to comprise more competencies than specific ones as they should be applicable job- or industry section-independently (e.g., Handbuch Kompetenzmessung (2007), Spencer and Spencer (1993), and Building Blocks Model (2017)). Additionally, these models often contain descriptions of the competencies contained, which may include one- or multidimensional competency levels. (Hagn, 2017).

Besides the differentiation of competency models regarding specific or general competencies, these models differ concerning the competency categories they are built on (May, Ossenberg, 2014). These can be taken over from an already existing competency model – or new ones may be used. If the categories are taken over, they may be adjusted (e.g., Armstrong and Henry (2009) and Lee (2010)). Moreover, parts from different existing models may be combined (e.g., Wiratmadja et al. (2014)). Two "general" categories are "personal" and "professional" competencies (May, Ossenberg, 2014). However, those are not contained in each of the models found in the literature review. Often, competencies are categorized due to similarities (Derro, Jansma, 2008; Hu et al., 2011). Cerinšek and Dolinšek (2011) do not follow this approach, as they assign the competencies in their model to specific process steps. The competency models found in the literature review do not understand competencies only as cognitive skills. They are defined as "cluster of related knowledge, skills, and abilities that affects a major part of one's job […]" (Advanced Manufacturing Competency Model, 2010, p. 3). (Hagn, 2017).

4.2.1.3 Industrial Sector- or Job-Specific Competency Models

Eleven of the 27 sources identified in the literature review describe competency models that refer to a specific job or industrial sector, or to a specific management level. While models for specifics jobs tend to comprise a high share of specific competencies and only few general ones, industrial sector-specific competency models are prone to contain competencies that are more general and less specific ones. (Hagn, 2017).

4.2.1.4 General Competency Models

Eleven of the 27 sources contain general competency models, i.e., models that can be applied not only to one, but different industrial sectors. Six of those are not suited for our purpose as they focus on specific competencies, e.g., only for senior management (Jin et al., 2006), for entrepreneurial competencies in combination with sustainability competencies (Lans et al., 2014), or for managers in combination with an effective work performance (Boyatzis, 1982). (Hagn, 2017).

The remaining five competency models are generally suited for a comprehensive collection of competencies. Hagn (2017) examined, which of those are best suited to cover the competencies that German companies mostly expect from graduates (Kompetent und Praxisnah, 2015), including important competencies such as "Ability to Communicate" and "Ability to Work in a Team" (Suleman, 2016). The results, which are presented in Table 19, show that the competency models described by Bartram (2005), in the Handbuch Kompetenzmessung (2007), and in Building Blocks Model (2017) cover most of these important general competencies. (Hagn, 2017).

Table 19: Occurrence of Competencies Mostly Expected from German Graduates in General Competency Models (with regards to Hagn (2017, p. 29))

Competency	Bartram (2005)	Bohlouli et al. (2017)	Hand-buch Kompe-tenzmess ung (2007)	Building Blocks Model (2017)	Wiratma dja et al. (2014)
Self-Management			X		
Analytic Skills	X		X	X	X
Decision-Making Ability	X		X	X	
Operational Readiness		X	X		X
Sense of Responsibility	X				
Learning Ability	X	X	(X)[51]	X	
Ability to Work under Pressure	X		X		
Entrepreneurial Spirit	X	X		X	
Initiative	X	X	X	X	X
Ability to Work in a Team	X	X	X	X	X
Ability to Communicate	(X)[52]	X	X	X	
Total	**8 (9)**	**6**	**8 (9)**	**7**	**4**

The competency model described by Bartram (2005) was introduced in section 2.6.3. It comprises three hierarchical levels, as first level the "Great Eight", as second level the "Competency Dimensions", and on third level 112 "Component Competencies". It serves as reference model for the first version of the competency model for employees in Industry 4.0 as presented in section 4.1.3 and in Prifti, Knigge, Kienegger, et al. (2017a) and Prifti, Knigge, Kienegger, et al. (2017b).

The competency model described in Building Blocks Model (2017) is illustrated as pyramid with nine layers that build on one another. The lowest level contains general competencies that can be applied in several areas, e.g., "Independent Action". The higher the level, the more specific are the competencies, from general over industrial sector-specific to job-specific. The model contains and defines 25 general and management competencies (Building Blocks Model, 2017). For each of those, sub-competencies and typical behaviour patterns are described. However, the general competency model does not specify industry sector- or job-specific competencies. In order to generate a complete competency model for an industry sector or a job, the corresponding competencies have to be specified as done in Advanced Manufacturing Competency Model (2010) for the industry sector "Advanced Manufacturing". It would be a possibility to implement this for Industry 4.0 as well. (Hagn, 2017).

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[51] The competency model of 2007) contains the competence "Willingness to Learn", not "Learning Ability". (Hagn, 2017).

[52] The competency model of Bartram (2005) contains competencies such as "Communicating Proactively" and "Targeting Communication", which are part of comprehensive communication skills. "Ability to communicate" is not contained. (Hagn, 2017).

The competency model described in the Handbuch Kompetenzmessung (2007) comprises 64 competencies. These are divided into the four categories “Personal Competencies”, “Domain-Specific Competencies”, “Social/Communication Competencies”, and “Activity-Based Competencies”. “Activity-Based Competencies” comprise competencies that are needed to act fair and organized. This explicitly includes the use of competencies from the other three competency categories (May, Ossenberg, 2014). Furthermore, the model comprises descriptions of typical behaviour patterns for each competency. In contrast to the other models, the original language of this model is German. (Hagn, 2017).

Although all three models described in this section are general competency models, there are big differences between them. While most competencies are described in the Handbuch Kompetenzmessung (2007), it uses only a flat hierarchy with only four categories. The models presented by Bartram (2005) and in the Handbuch Kompetenzmessung (2007) comprise clearly less competencies. However, they make use of more competency categories and hierarchical levels. These three competency models have in common that they are widely used in practice (Aerospace and Defense Manufacturing Competency Model, 2017; Framework., 2017; Heyse, 2017; Iliescu, 2012; Manufacturing Competency Model, 2017) and describe typical behaviours of (sub-)competencies. (Hagn, 2017).

4.2.1.5 Competency Models for Industry 4.0 from Literature

In the literature review on competency models, the four competency models for Industry 4.0 listed in Table 13 were identified. (Hagn, 2017).

Table 20: Competency Models for Industry 4.0 Identified in the Literature Review

No.	Title	Concepts				References
		Industry 4.0	General	Industrial Sector	Job/ Level	
1	“Kompetenzentwicklungsstudie Industrie 4.0: Erste Ergebnisse und Schlussfolgerungen” [53]	X		X		Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016)
10	“Tangible Industry 4.0: A Scenario-Based Approach to Learning for the Future of Production”	X		X		Erol et al. (2016)
20	“A Competency Model for “Industrie 4.0” Employees”	X				Prifti, Knigge, Kienegger, et al. (2017a)
25	“Industry 4.0 - A Discussion of Qualifications and Skills in the Factory of the Future: A German and American Perspective”	X		X	X	Gehrke et al. (2015)

[53] Competency Development Study Industry 4.0: First Results and Conclusions. Translated by the author.

The competency model published by Prifti, Knigge, Kienegger, et al. (2017a) was developed in the scope of the same research project as this thesis. Its development is described in detail in sections 3.4, 3.5, and 4.1.Erol et al. (2016) based their competency model for Industry 4.0 on a literature review. Gehrke et al. (2015) derive their model from expected future tasks. The Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) base their model on a survey among companies. (Hagn, 2017).

The Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) identified in their study, which focussed on automotive and engineering companies, both, organizational as well as individual competencies. They group the competencies into three categories: Technology/Data, Processes/Customers, and Infrastructure/Organization. While large companies focus on competencies in the category Technology/Data, SMEs tend to focus the category of Processes/Customers (Deutsche Akademie der Technikwissenschaften (acatech) et al., 2016). Further, the model concentrates on individual competencies and only comprises competencies for Industry 4.0. Thus, it contains only thirteen competencies – and lacks of general competencies such as the capacity for teamwork (Suleman, 2016). Therefore, this model is not suited for a comprehensive classification of applicants. The competencies are not tailored for a specific job or management level. The three competency categories used in this model were not found in other models. They do not allow a differentiation between domain specific and individual competencies (May, Ossenberg, 2014). (Hagn, 2017).

Erol et al. (2016) derive the competencies for their competency model from literature on a high detail level – which results in a large number of competencies. E.g., while the competency model of the Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016) includes the competency "Social Competence" [sic!], the model of Erol et al. (2016) differentiates between "Co-Operation", "Working in Interdisciplinary and Interorganizational Teams" and "Conflict and Mediation Ability". In their competency model, Erol et al. (2016) divide their competencies into the categories as proposed by Erpenbeck et al. (2013): "Personal Competencies", "Domain-Specific Competencies", "Social/Communication Competencies", and "Activity-Based Competencies". Erol et al. (2016) differentiate between competencies for workers, engineers, or managers, and competencies needed by employees. The domain-specific competencies in this model focus on competencies for the production of the future – however, further industrial section- or process-specific competencies may be needed (Erol et al., 2016). Like the competency model for Industry 4.0 proposed by the Deutsche Akademie der Technikwissenschaften (acatech) et al. (2016), the competency model of Erol et al. (2016) cannot be used intersectorally. (Hagn, 2017).

Gehrke et al. (2015) describe a competency model that is divided into two categories: personal and technical competencies as proposed by May and Ossenberg (2014). Additionally, they classify the competencies into mandatory, target, and obligatory competencies. Overall, the competencies presented in this model are similar to those presented by Erol et al. (2016). However, this model contains some additional competencies such as "Knowledge Management", "Awareness for IT Security", "Legal Aspects", and "Selfmanagement and Timemanagement". The competency model comprises only competencies for workers; management competencies are not contained. This avoids the overall application of this competency model. (Hagn, 2017).

The formerly in this work developed competency model for employees in Industry 4.0 contains the 68 competencies for Industry 4.0 derived from literature and focus groups. The general competencies from the SHL UCF as proposed by Bartram (2005) were not included, e.g., “Acting on Own Initiative” or “Coping with Pressure” (Bartram, 2005, p. 1202). This competency model is not restricted to a specific management level. However, it focusses on domain-specific competencies for IS, IT, and Engineering. (Hagn, 2017).

All of the four models comprise Industry 4.0-specific competencies. None of the models is complete regarding general competencies. The most mentioned competencies are soft skills, social competencies, and generic IT competencies. These competencies also determine the current discussion of qualification for Industry 4.0 (Pfeiffer, 2015), which explains the high share of generic competencies in comparison to other industrial sector-specific competency models. The model proposed by Prifti, Knigge, Kienegger, et al. (2017a) is the most comprehensive of all four. However, it lacks of general competencies – which can be derived from the analysis of job offers, as these usually comprise these general competencies. While conducting the analysis of job offers (cp. sections 3.7 and 4.3), we discovered that the definition of the competencies in the competency model for employees in Industry 4.0 as proposed by Prifti, Knigge, Kienegger, et al. (2017a) are not always clear enough to easily assign the competencies found in the job offers analysis. (Hagn, 2017). Therefore, besides adding further competencies to the first version of our competency model, we redefined and/or adjusted the wording of some of the competencies contained in the model (cp. section 4.3.3).

4.2.2 Development of a Combined Competency Model Including General and Industry 4.0-Specific Competencies

For building a comprehensive competency model for employees in Industry 4.0, we decided to combine two of the competency models described in section 4.2.1 in order to reach a wide coverage of both, Industry 4.0-specific competencies as well as general competencies. As it is the most comprehensive competency model for Industry 4.0, we decided to use our formerly developed competency model for employees in Industry 4.0 as presented in section 4.1.3 and published in Prifti, Knigge, Kienegger, et al. (2017a) and Prifti, Knigge, Kienegger, et al. (2017b) to cover the Industry 4.0-specific competencies. One of the limitations of this competency model isits lacks of insights from practice. Therefore, we add our findings from TM on online job offers. In the case of general competency models, several models are worth to be considered. In section 4.2.1.4, we came to the conclusion, that the competency models presented by Bartram (2005), in the Handbuch Kompetenzmessung (2007), and in Building Blocks Model (2017) are best suited for our case.

The combination of our first version of a competency model for employees in Industry 4.0 with the general model of Bartram (2005) seemed to be an obvious solution, as our competency model relies on the structure of that presented by Bartram (2005), i.e., they use the same structure. However, in our competency model we adjusted the “Competency Components” – so this would have to be combined with those in the model of Bartram (2005) again. When we came to the point that we wanted to add the competencies extracted from online job offers as well, this model seemed to be too detailed for an easy assignment of the extracted competencies to the “Competency Components”. (Hagn, 2017).

A second option would be to combine our first version of the competency model for employees in Industry 4.0 with the model presented by Erpenbeck in the Handbuch Kompetenzmessung (2007). In this case, our competency model builds on the more complex structure and contains more categories and hierarchical levels. This allows an easier assignment of the competencies extracted from job offers to the model. Therefore, the competencies presented in the Handbuch Kompetenzmessung (2007) would have to be transferred to our competency model first. The competency model presented in the Handbuch Kompetenzmessung (2007) is in German language. (Hagn, 2017).

A combination of our competency model for employees in Industry 4.0 with the competency model presented in Building Blocks Model (2017) would be easily possible. The Industry 4.0-specific competencies could be integrated in the model in the area that is provided for industry sector- or job-specific competencies. (Hagn, 2017).

The online job offers we extracted competencies for Industry 4.0 from are in German language as well. Together with the possibility of easily integrating the two models with one another, these were the reasons why we decided to integrate our first version of a competency model for employees in Industry 4.0 with that presented by Erpenbeck in the Handbuch Kompetenzmessung (2007). (Hagn, 2017).

In the scope of this thesis, the results – and therefore the competency model for employees in Industry 4.0 – are presented in English. Moreover, the results from a second, long-term analysis of German online job offers were added. Thus, we start with combining our first version of the competency model for employees in Industry 4.0 with that presented in the Handbuch Kompetenzmessung (2007) – in English language. Frist, we translated the competency terms of the model presented by Erpenbeck. If there was no exactly corresponding term in our first version of the competency model, we kept both terms. Next, we checked, which terms of the model presented by Erpenbeck were already contained in our competency model. E.g., “Lernbereitschaft” – “Willingness to Learn” from the model of Erpenbeck was not contained in our competency model so far. However, it was contained in “Life-Long Learning” from our competency model. Therefore, no new competency had to be added to the model in this case. Competencies that could not be found in our model so far were assigned to the competency dimension with the greatest fit. For a higher clarity, we decided to proceed with the approach of Hagn (2017), who presents the domain-specific competencies in a second table. Table 21 shows the combined competency model for Industry 4.0. Table 22 shows the domain-specific competencies for Industry 4.0 for the areas of Business Informatics/IS, Computer Sciences/Informatics, and Engineering. In both tables, competencies that have been added from the model presented in the Handbuch Kompetenzmessung (2007) are italized.

Table 21: Competency Model for Industry 4.0 - Combination of an Industry 4.0-Specific and a General Competency Model: General Competencies (with regards to Hagn (2017, p. 33 ff.), Prifti, Knigge, Kienegger, et al. (2017a, p. 56 f.), and Bartram (2005, p. 1202 f.))

Great Eight	Competency Dimension	Competencies
1) Leading and Deciding	a) Deciding and Initiation Action	• Decision Making • Taking Responsibility • *Ability and Willingness to Take the Initiative* • *Consequence in Acting* • *Energy*
	b) Leading and Supervising	• Leadership Skills
2) Supporting and Cooperating	a) Working with People	• Teamwork • Collaborating with Others • Communicating with People
	b) Adhering to Principles and Values	• *Loyalty* • Respecting Ethics • Environmental Awareness • Awareness for Ergonomics • *Social Commitment*
3) Interacting and Presenting	a) Relating and Networking	• Compromising • Creating Business Networks • Maintaining Customer Relationships • *Conflict Management Skills*
	b) Persuading and Influenc-ing	• Negotiating • Emotional Intelligence • *Ability to Initiate Action* • *Quick-Wittedness* • *Acquisition Skills* • *Consulting Skills*
	c) Presenting and Com-municating Information	• Presentation and Communication Ability • *Linguistic Elegance*
4) Analyzing and Interpreting	a) Writing and Reporting	• Targeted/Technical Communication • Literacy
	b) Applying Expertise and Technology	• Domain-Specific Knowledge (cp. Table 22)
	c) Analyzing	• Problem Solving • Optimization • Analytical Abilities • Cognitive Ability • *Objectivity*
5) Creating and Conceptualizing	a) Learning and Research-ing	• Life-Long Learning • Knowledge Management
	b) Creating and Innovating	• Innovating

Great Eight	Competency Dimension	Competencies
		• Creativity • Critical Thinking • Change Management • *Creative Drive*
	c) Formulating Strategies and Concepts	• Capacity for Holistic Thinking • *Apply Systematic and Methodical Approaches* • *Conceptual Strength* • Business Strategy • Abstraction Ability • Managing Complexity
6) Organizing and Executing	a) Planning and Organizing	• Project Management • Planning and Organizing Work • Management Ability
	b) Delivering Results and Meeting Customer Expec-tations	• Customer Orientation • Customer Relationship Management (CRM)
	c) Following Instructions and Procedures	• *Willingness to Work* • *Reliability* • *Diligence* • *Discipline* • *Conscientiousness* • Legislation Awareness • Safety Awareness • Individual Responsibility
7) Adapting and Coping	a) Adapting and Respond-ing to Change	• Work in Interdisciplinary Environments • Intercultural Competency • Flexibility • Adaptability and Ability to Change Mind-Sets
	b) Coping with Pressure	• Work-Life Balance • *Ability to Work Under Pressure* • *Optimism*
8) Enterprising and Performing	a) Achieving Personal Work Goals and Objectives	• Self-Management and -Organization • *Tenacity* • *Commitment and Willingness* • *Result-Oriented Acting*
	b) Entrepreneurial and Commercial Thinking	• Business Model Understanding • Entrepreneurship • *Market Expertise*

Table 22: Competency Model for Industry 4.0 - Combination of an Industry 4.0-Specific and a General Competency Model: Domain-Specific Competencies (with regards to Hagn (2017, p. 35), Prifti, Knigge, Kienegger, et al. (2017a, p. 56 f.), and Bartram (2005, p. 1202 f.))

<table>
<tr><th rowspan="2">Competency Dimension</th><th colspan="3">Competencies</th></tr>
<tr><th>Business Informatics/ Information Systems</th><th>Computer Sciences/ Informatics</th><th>Engineering</th></tr>
<tr><td rowspan="4">Domain-Specific Knowledge:

4) b) Applying Expertise and Technology</td><td colspan="3">• IT and Technology Affinity
• Economics
• Extract Business Value from Social Media
• Multidisciplinary Knowledge
• Teaching Ability</td></tr>
<tr><td>• Service Orientation/ Product Service Offering
• Process Management/ Business Process Management (BPM)
• 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 Analytics and Interpretation
• Cloud Computing/Architectures
• In-Memory DBs
• Statistics
• Data Security</td><td></td></tr>
</table>

4.3 Development of a Comprehensive Competency Model for Employees in Industry 4.0

The first version of our competency model for employees in Industry 4.0 is an Industry 4.0-specific competency model and lacks of general competencies. Thus, we combined it with the competency model presented by Erpenbeck in the Handbuch Kompetenzmessung (2007) to a second version, the “combined” competency model for employees in Industry 4.0 (cp. section

4.2.2). Still, this combined model only relies on findings from literature and focus groups with teaching staff from institutions of (higher) education. Thus, it mostly neglects the view from practice. We now add a view from practice by considering the results of our project regarding TM on German online job offers for Industry 4.0-related jobs. The project, including technical details of our TM application and our two data sets is described in section 3.7. In this section, we use the results of the TM for validating the combined competency model for employees in Industry 4.0 presented in section 4.2.2 – and extended it with additional findings.

4.3.1 Frequency Analysis for Evaluating and Extending the Set of Competencies for Industry 4.0

A frequency analysis examines the absolute and the relative frequency of a word in a given data set. This can be conducted for the accurate diction of the word – or for all words with the same stem (Dzudzek et al., 2009). We conducted a frequency analysis for the competencies in the combined competency model for employees in Industry 4.0 presented in section 4.2.2. Multiple mentions of a competency in one job offer were counted as one. First, we examined which competencies from our combined competency model were not – or only rarely – demanded in the German online job offers. This allowed us to discover obsolete competencies (Bensberg, Buscher, 2016b). In our first data set, the seven competencies listed in Table 23 were not contained. (Hagn, 2017).

Table 23: Obsolete Competencies with Regards to the First Data Set of German Online Job Offers (with regards to Hagn (2017))

Competency	Origin
Awareness for Ergonomics (2.b)	Prifti, Knigge, Kienegger, et al. (2017a)
Compromising (3.a)	Prifti, Knigge, Kienegger, et al. (2017a)
Quick-Wittedness (3.b)	Handbuch Kompetenzmessung (2007)
Literacy (4.a)	Prifti, Knigge, Kienegger, et al. (2017a)
Business Change Management (4.b)	Prifti, Knigge, Kienegger, et al. (2017a)
Objectivity (4.c)	Handbuch Kompetenzmessung (2007)
Optimizm (7.b)	Handbuch Kompetenzmessung (2007)

Table 24 contains competencies that were not listed in the second data set. The first section includes competencies that have not been mentioned at all, the second section includes competencies that have been mentioned less than five times.

Table 24: Obsolete Competencies with Regards to the Second Data Set of German Online Job Offers

Competency	Origin
Environmental Awareness (2.b)	Prifti, Knigge, Kienegger, et al. (2017a)
Awareness for Ergonomics (2.b)	Prifti, Knigge, Kienegger, et al. (2017a)
Compromising (3.a)	Prifti, Knigge, Kienegger, et al. (2017a)
Creating Business Networks (3.a)	Prifti, Knigge, Kienegger, et al. (2017a)
Understand and Coordinate Workflows (4.b)	Prifti, Knigge, Kienegger, et al. (2017a)
Business Change Management (4.b)	Prifti, Knigge, Kienegger, et al. (2017a)
Multidisciplinary Knowledge (4.b)	Handbuch Kompetenzmessung (2007)

Competency	Origin
Respecting Ethics (2.b)	Prifti, Knigge, Kienegger, et al. (2017a)
Social Commitment (2.b)	Handbuch Kompetenzmessung (2007)
Quick-Wittedness (3.b)	Handbuch Kompetenzmessung (2007)
In-Memory DBs (4.b)	Prifti, Knigge, Kienegger, et al. (2017a)
Teaching Ability (4.b)	Handbuch Kompetenzmessung (2007)
Network Security (4.b)	Prifti, Knigge, Kienegger, et al. (2017a)
Objectivity (4.c)	Handbuch Kompetenzmessung (2007)
Optimizm (7.b)	Handbuch Kompetenzmessung (2007)

There are two possibilities why these competencies did not – or only rarely – appear in our result set: Either they were not mentioned in the job offers – or they were not identified by our analysis. A manual examination of the results of data set 1 revealed, that the competencies were not contained in the job offers (Hagn, 2017). As we did not change our TM application, we assume that the competencies, which do not – or hardly – appear in our result set, are not contained in data set 2 (more often). This may be because they are not needed by the market, because they a too general to mention them (e.g., "Literacy"), because they may be included in other competencies (e.g., the "Ability to Compromise" may be seen as part of the "Ability to Work in a Team") – or because they are "too new" (e.g., "In-Memory DBs").

It is obvious, that with one exception all competencies of the Competency Dimension 2.b "Supporting and Cooperating – Adhering to Principles and Values" are contained in these lists. We believe these competencies to be important in companies, as many companies have their internal "code of conduct" or similar documents. However, these competencies are obviously not mentioned in job offers – probably as they are seen as self-evident requirement. A lot of the other competencies listed in Table 23 and Table 24 belong to section 4.b "Analyzing and Interpreting – Applying Expertise and Technology", where we embedded the domain-specific knowledge in our model. Thus, we assume that the competencies not or hardly found in our data sets are too special or too new to be found in the job offers more often. With respect to this explanation, we decided not to delete any of the competencies listed in Table 23 and Table 24 from our competency model, but to print them in a lighter colour (for less importance).

Second, we analysed which competencies from our combined competency model were mentioned the most in the German online job offers. The results for data set 1 are illustrated in Figure 18.

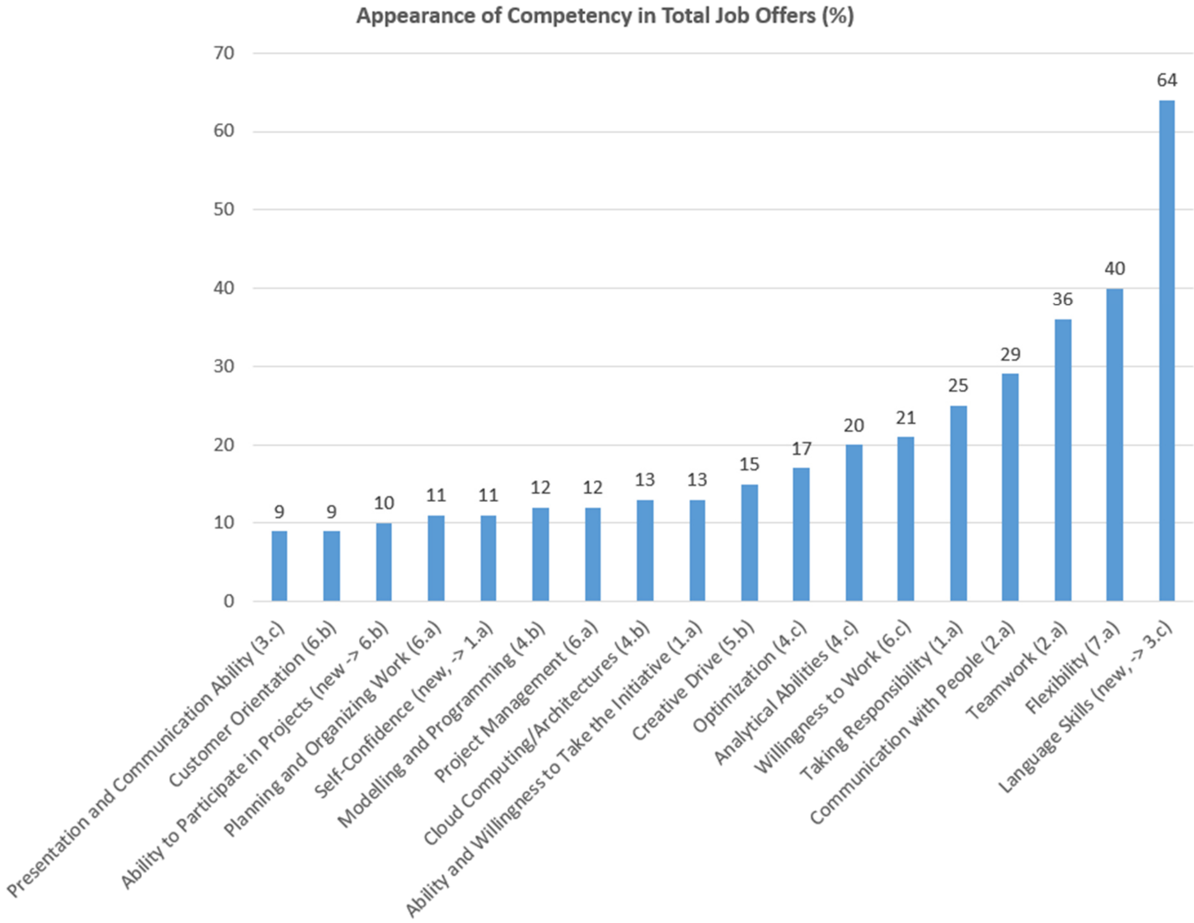

Figure 18: Competencies Commonest Extracted From Data Set 1 (with regards to Hagn (2017))

Two of these competencies, “Cloud Computing/-Architectures” and “Modelling and Programming”, are domain-specific competencies. The rest of the competencies are general competencies. McPherson et al. (2016) emphasize that these general competencies are very important – but not considered well enough in education. (Hagn, 2017). The most mentioned competency is language skills, which includes a high number of references of “German language” and “English language”. Therefore, we decided to add “Language Skills” to the competency model with focus on “different languages” in the Competency Component “Interacting and Presenting - Presenting and Communicating Information”. Moreover, because they are comprised in the group of the commonest found competencies in data set 1, we added “Self Confidence” and “Ability to Participate in Projects” to the model (cp. section 4.3.4).

The top 20 competencies mentioned in our second data set are shown in Figure 19. In these results, we find three domain-specific competencies: “Cloud Computing/-Architectures” and “Modelling and Programming” as in the first data set, and the new competency “Ability to Participate in Projects” (cp. section 4.3.2). In general, we see the same competencies as in the analysis of the first data set, however, with slight changes in the order – and with lower percentages. This may be because it is a different data set collected in a different period of time– we would have to apply our analysis to more data sets to validate the shares of the competencies of the overall data sets. However, we can see big similarities in which competencies are mentioned the most. These will be printed bold in the model (for a higher importance).

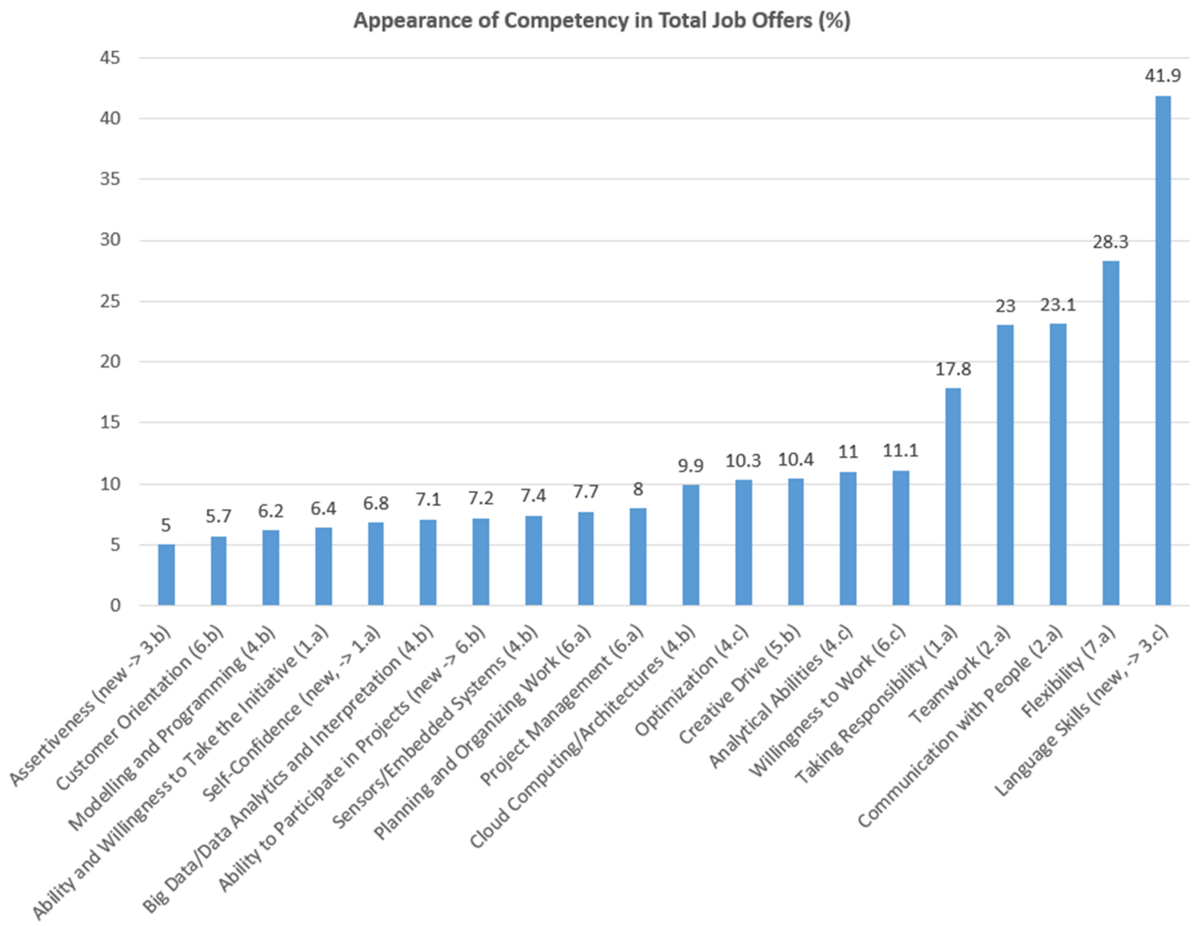

Figure 19: Competencies Commonest Extracted from Data Set 2

4.3.2 Fulltext Index Analysis for Discovering New Industry 4.0-Relevant Competencies

While applying TA to our data sets, we analysed the results that included enumerations of competencies to discover new competencies from the data sets. As described in section 3.7.4.2, we were able to extract five new competencies from our first data set. Next, we assign these competencies to the Competency Dimensions of our model as listed in Table 25 with regards to Hagn (2017).

Table 25: New Competencies Derived from Data Set 1 (with regards to Hagn (2017))

New Competency	Great Eight – Competency Dimension
Self-Confidence	Leading and Deciding – Deciding and Initiating Action
Integrity	Supporting and Cooperating – Adhering to Principles and Values
Assertiveness	Interacting and Presenting – Persuading and Influencing
Moderation Skills	Interacting and Presenting – Presentation and Communicating Information
Ability to Participate in Projects	Organizing and Executing – Delivering Results

From the second data set, we extracted 36 competencies that were not comprised in our competency model so far. We decided to integrate the eight competencies listed in Table 26 in our model, as they appeared at least five times to guarantee that they are not just uniquely mentioned by a specific company for a specific job.

Table 26: New Competencies Derived from Data Set 2

New Competency	Count	Great Eight – Competency Dimension
Goal-Oriented Acting	36	Enterprising and Performing – Achieving Personal Work Goals and Objectives
Solution-Oriented Acting	12	Enterprising and Performing – Achieving Personal Work Goals and Objectives
Persuasive Power	9	Interacting and Presenting – Persuading and Influencing
Coordination	9	Organizing and Executing – Planning and Organizing
Quality-Oriented Acting	8	Enterprising and Performing – Achieving Personal Work Goals and Objectives
Enthusiasm	8	Interacting and Presenting – Persuading and Influencing
Escalation Management Ability	5	Adapting and Coping – Coping with Pressure
Server Technology Skills	5	Analyzing and Interpreting – Applying Expertise and Technology

The general competencies which are not taken over into the competency model are the following: “Requirement Management Skills”, “Ability to Abstract”, “Ability to Reason”, “Ability to Judge”, “Sales-Oriented Behaviour”, “Time Management”, “Risk Management Skills”, “Interpersonal Skills”, “Power of Concentration”, and “Critical Ability”. The domain-specific competencies which appear in the analysis but are not taken over into the competency model are the following: “Edge Solutions”, “System Development”, “Optical Technologies Knowledge”, “Auditing Knowledge”, “Conceptional Skills”, “IoT Knowledge”, “DevOps Knowledge”, “E-Commerce Knowledge”, “Data Integration Skills”, “System Integration Skills”, “Automation Skills”, “Personal Computer (PC) Administration Skills”, “Storage Technology Skills”, “Database Technology Skills”, “Sourcing Strategy Knowledge”, and “Construction Ability”. In the future, they may gain more importance – and may then be added to the model.

4.3.3 Linguistical Revision of the Competency Model for Employees in Industry 4.0

While building the comprehensive competency model for employees in Industry 4.0, we conducted a linguistical revision on the competencies on the third hierarchical level in order to harmonize and smooth the wordings. This was required as we developed the models from sources of different languages: German and English. For the linguistical revision, we used the online dictionaries English Oxford Living Dictionaries[54], LEO[55], and Linguee[56] as well as the help of two residents of London, UK. The transfer list for changed competency terms is given in Table 27. As we see a difference between targeted and technical communication, the competency “Targeted/Technical Communication” is split up into the two competencies “Targeted

[54] English Oxford Living Dictionaries: Online dictionary, provided by OXFORD University Press. https://en.oxforddictionaries.com/. Accessed on August 31st, 2018.
[55] LEO: Online dictionary, provided by LEO GmbH. https://www.leo.org/ Accessed on August 31st, 2018.
[56] Linguee: Online dictionary, provided by the DeepL GmbH. https://www.linguee.de/. Accessed on August 31st, 2018.

Communication Skills" and "Technical Communication Skills". We applied the same to some other competencies, which is documented in Table 27. In contrast to the former, we aggregated "Change Management" and "Business Change Management" to "Change Management Skills" as we do not see a significant difference between both terms. We assigned the "Change Management Skills" to the general section of the model, as we do not rate them as domain- or industrial sector-specific competencies. We deleted "Management Ability" from section 6.a – as it is too unspecific. Its aspects are contained in the other items of 6.a – or in other sections (e.g., "Leadership Skills" in 1.a). The first and second hierarchical levels (the "Great Eight" and the Competency Dimensions) remain untouched.

Table 27: Linguistical Revision of Competency Terms

Combined Competency Model	→ Comprehensive Competency Model
Decision Making (1.a)	Decision-Making Ability (1.a)
Taking Responsibility (1.a)	Ability and Willingness to Take Responsibility (1.a)
Teamwork (2.a)	Teamwork Ability (2.a)
Collaborating with Others (2.a)	Ability and Willingness to Collaborate (2.a)
Communication (2.a)	Communication Skills (2.a)
Respecting Ethics (2.b)	Ethical Behaviour (2.b)
Communicating with People (2.a)	Communication Skills (2.a)
Compromising (3.a)	Ability and Willingness to Compromise (3.a)
Creating Business Networks (3.a)	Business Networking Skills (3.a)
Maintaining Customer Relationships (3.a)	Customer Relationship Management Skills (3.a)
Negotiating (3.b)	Negotiation Skills (3.b)
Economics (4.b)	Economic Knowledge (4.b)
Extract Business Value from Social Media (4.b)	Ability to use Social Media for Business (4.b)
Understand and Coordinate Workflows (4.b)	Ability to Use Workflows (4.b)
Network Security (4.b)	Network Security Understanding (4.b)
IT Architectures (4.b)	IT Architecture Understanding (4.b)
Machine Learning (4.b)	Machine Learning Skills (4.b)
System Development (4.b)	System Development Skills (4.b)
Integrating Heterogeneous Technologies (4.b)	Ability to Handle Heterogeneous Technologies (4.b)
Mobile Technologies (4.b)	Mobile Technologies Skills (4.b)
Predictive Maintenance (4b)	Predictive Maintenance Skills (4.b)
In-Memory DBs (4.b)	In-Memory Computing Skills (4.b)
Statistics (4.b)	Statistics Skills (4.b)
Data Security (4.b)	Data Security Skills (4.b)
Problem Solving (4.c)	Problem-Solving Competency (4.c)
Optimization (4.c)	Optimization Skills (4.c)
Analytical Abilities (4.c)	Analytical Thinking Ability (4.c)

Combined Competency Model	→ Comprehensive Competency Model
Cognitive Ability (4.c)	Cognitive Skills (4.c)
Life-Long Learning (5.a)	Capacity for Life-Long Learning (5.a)
Knowledge Management (5.a)	Knowledge Management Skills (5.a)
Innovating (5.b)	Innovation Management Skills (5.b)
Critical Thinking (5.b)	Ability for Critical Thinking (5.b)
Business Strategy (5.c)	Business Strategy Understanding (5.c)
Abstraction Ability (5.c)	Ability to Abstract (5.c)
Managing Complexity (5.c)	Ability to Manage Complexity (5.c)
Project Management (6.a)	Project Management Skills (6.a)
Planning and Organizing Work (6.a)	Planning and Organizing Skills (6.a)
Customer Orientation (6.b)	Customer-Oriented Behaviour (6.b)
Customer Relationship Management (CRM) (6.b)	Customer-Specific Communication (6.b)
Safety Awareness (6.c)	Security Awareness (6.c)
Work in Interdisciplinary Environments (7.a)	Ability to Work in Interdisciplinary Environments (7.a)
Work-Life Balance (7.b)	Awareness for Work-Life Balance (7.b)
Self-Management and –Organization (8.a)	Self-Management and Self-Organization Skills (8.a)
Entrepreneurship (8.b)	Entrepreneurial Spirit and Thought (8.b)
Social Commitment (2.b)	Social Skills (2.a)
	Social Commitment (2.b)
Presentation and Communication Ability (3.c)	Presentation Skills (3.c)
	Communication Skills (3.c)
Targeted/Technical Communication (4.a)	Targeted Communication Skills (4.a)
	Technical Communication Skills (4.a)
IT and Technology Affinity (4.b)	IT Affinity (4.b)
	Technology Affinity (4.b)
Process Management/Business Process Management (BPM) (4.b)	Process Management Understanding (4.b)
	Business Process Management Understanding (4.b)
Service Orientation/Product Service Offering (4.b)	Service Orientation (4.b)
	Knowledge about Product-Service-Offerings (4.b)
Sensors/Embedded Systems (4.b)	Sensor Technology Understanding (4.b)
	Embedded System Skills (4.b)
Network Technology/M2M Communication (4.b)	Network Technology Skills (4.b)
	M2M Communication Skills (4.b)
Robotics/Artificial Intelligence (4.b)	Robotics Skills (4.b)
	Artificial Intelligence Skills (4.b)
Modelling and Programming (4.b)	Modelling Skills (4.b)
	Programming Skills (4.b)
	Big Data Management Skills (4.b)

Combined Competency Model	→ Comprehensive Competency Model
Big Data/Big Data Analytics and Interpretation (4.b)	Smart Data Analytics Skills (4.b)
Cloud Computing/Architectures (4.b)	Cloud Computing Skills (4.b)
	Cloud Computing Architectures Understanding (4.b)
Business Change Management	Change Management Skills
Change Management	
Management Ability (6.a)	Deleted – too unspecific, contained in other items, such as Project Management Skills (6.a), Planning and Organizing Skills (6.a), Decision-Making Ability (1.a), Leadership Skills (1.b)

4.3.4 A Comprehensive Competency Model for Employees in Industry 4.0.

Building on the combined competency model for employees in Industry 4.0 as presented in section 4.2.2 and enhancing it with the results described in sections 4.3.2 and 4.3.3, we finally can present our comprehensive competency model for employees in Industry 4.0 in Table 28. This competency model contains general competencies for Industry 4.0. The competencies that were contained or derived from the top twenty competencies mentioned in the job offers are written in bold. Competencies that were not – or only up to five times – found in the job offers are written in grey and in italics. Domain-specific competencies have to be collected with regards to the domain in focus. We developed and present domain-specific sections for the areas of Business Informatics/IS (Table 29), Informatics/Computer Sciences (Table 30), and Engineering (Table 31). This list of domain-specific sections may be extended in the future concerning different areas, such as economics, and industrial sectors, e.g., automotive or banking.

Table 28: A Comprehensive Competency Model for Employees in Industry 4.0 (with regards to Hagn (2017, p. 33 ff.), Prifti, Knigge, Kienegger, et al. (2017a, p. 56 f.), and Bartram (2005, p. 1202 f.))

Great Eight	Competency Dimension	Competencies
1) Leading and Deciding	a) Deciding and Initiating Action	• Decision Making Ability • **Ability and Willingness to Take Responsibility** • **Ability and Willingness to Take the Initiative** • Consequence in Acting • Energy • **Self-Confidence**
	b) Leading and Supervising	• Leadership Skills
2) Supporting and Cooperating	a) Working with People	• **Teamwork Ability** • Ability and Willingness to Collaborate • **Communication Skills** • Social Skills

Great Eight	Competency Dimension	Competencies
	b) Adhering to Principles and Values	• Loyalty • *Ethical Behaviour* • *Environmental Awareness* • *Awareness for Ergonomics* • *Social Commitment* • Integrity
3) Interacting and Presenting	a) Relating and Networking	• Ability and Willingness to Compromise • *Business Networking Skills* • Customer Relationship Management Skills • *Conflict Management Skills*
	b) Persuading and Influencing	• Negotiation Skills • Emotional Intelligence • Ability to Initiate Action • *Quick-Wittedness* • Acquisition Skills • Consulting Skills • **Assertiveness** • Persuasive Power • Enthusiasm
	c) Presenting and Communicating Information	• Presentation Skills • Linguistic Elegance • Moderation Skills • **Language Skills**
4) Analyzing and Interpreting	a) Writing and Reporting	• Targeted Communication Skills • Technical Communication Skills • *Literacy*
	b) Applying Expertise and Technology	• ***Domain-Specific Knowledge (cp. separate tables)***
	c) Analyzing	• Problem-Solving Competency • **Optimization Skills** • Cognitive Skills • **Analytical Thinking Ability** • *Objectivity*
5) Creating and Conceptualizing	a) Learning and Researching	• Capacity for Life-Long Learning • Knowledge Management Skills
	b) Creating and Innovating	• Innovation Management Skills • Creativity • Ability for Critical Thinking • Change Management Skills • **Creative Drive**
	c) Formulating Strategies and Concepts	• Capacity for Holistic Thinking • Apply Systematic and Methodical Approaches

Great Eight	Competency Dimension	Competencies
		• Conceptual Strength • Business Strategy Understanding • Ability to Abstract • Ability to Manage Complexity
6) Organizing and Executing	a) Planning and Organizing	• **Project Management Skills** • **Planning and Organizing Skills** • Coordination
	b) Delivering Results and Meeting Customer Expectations	• **Customer-Oriented Behaviour** • Customer-Specific Communication • **Ability to Participate in Projects**
	c) Following Instructions and Procedures	• **Willingness to Work** • Reliability • Diligence • Discipline • Conscientiousness • Legislation Awareness • Security Awareness • Individual Responsibility
7) Adapting and Coping	a) Adapting and Responding to Change	• Ability to Work in Interdisciplinary Environments • Intercultural Competency • Flexibility • Adaptability and Ability to Change Mind-Sets
	b) Coping with Pressure	• Awareness for Work-Life Balance • Ability to Work Under Pressure • *Optimism* • Escalation Management Ability
8) Enterprising and Performing	a) Achieving Personal Work Goals and Objectives	• Self-Management and Self-Organization Skills • Tenacity • Operational Readiness • Result-Oriented Acting • Goal-Oriented Acting • Solution-Oriented Acting • Quality-Oriented Acting
	b) Entrepreneurial and Commercial Thinking	• Business Model Understanding • Entrepreneurial Spirit and Thought • Market Expertise

Table 29: A Competency Model for Employees in Industry 4.0 – Combination of an Industry 4.0-Specific and a General Competency Model: Domain-Specific Competencies for Business Informatics/IS (with regards to Hagn (2017, p. 35), Prifti, Knigge, Kienegger, et al. (2017a, p. 56 f.), and Bartram (2005, p. 1202 f.))

Competency Dimension	Competencies for Business Informatics/ Information Systems
Domain-Specific Knowledge: **4) b) Applying Expertise and Technology**	• IT Affinity • Technology Affinity • Economic Knowledge • Ability to use Social Media for Business • *Multidisciplinary Knowledge* • *Teaching Ability* • Service Orientation • Knowledge about Product-Service-Offerings • Process Management Understanding • Business Process Management Understanding • *Ability to Use Workflows* • **Modelling Skills** • **Programming Skills** • **Big Data Management Skills** • **Smart Data Analytics Skills** • **Cloud Computing Skills** • **Cloud Computing Architectures Understanding** • *In-Memory Computing Skills* • Statistics Skills • Data Security Skills

Table 30: A Competency Model for Employees in Industry 4.0 – Combination of an Industry 4.0-Specific and a General Competency Model: Domain-Specific Competencies for Computer Sciences/Informatics (with regards to Hagn (2017, p. 35), Prifti, Knigge, Kienegger, et al. (2017a, p. 56 f.), and Bartram (2005, p. 1202 f.))

Competency Dimension	Competencies Computer Sciences/ Informatics
Domain-Specific Knowledge: **4) b) Applying Expertise and Technology**	• IT Affinity • Technology Affinity • Economic Knowledge • Ability to use Social Media for Business • *Multidisciplinary Knowledge* • *Teaching Ability* • *Network Security Understanding* • IT Architecture Understanding • Machine Learning Skills • System Development Skills • Ability to Handle Heterogeneous Technologies • Mobile Technologies Skills • **Sensor Technology Understanding** • **Embedded Systems Skills** • Network Technology Skills • M2M Communication Skills • Robotics Skills • Artificial Intelligence Skills • Predictive Maintenance Skills • **Modelling Skills** • **Programming Skills** • **Big Data Management Skills** • **Smart Data Analytics Skills** • **Cloud Computing Skills** • **Cloud Computing Architectures Understanding** • *In-Memory Computing Skills* • Statistics Skills • Data Security Skills • Server Technology Skills

Table 31: A Competency Model for Employees in Industry 4.0 – Combination of an Industry 4.0-Specific and a General Competency Model: Domain-Specific Competencies for Engineering (with regards to Hagn (2017, p. 35), Prifti, Knigge, Kienegger, et al. (2017a, p. 56 f.), and Bartram (2005, p. 1202 f.))

Competency Dimension	Competencies for Engineering
Domain-Specific Knowledge: **4) b) Applying Expertise and Technology**	• IT Affinity • Technology Affinity • Economic Knowledge • Ability to use Social Media for Business • *Multidisciplinary Knowledge* • *Teaching Ability* • System Development Skills • Ability to Handle Heterogeneous Technologies • Mobile Technologies Skills • **Sensor Technology Understanding** • **Embedded Systems Skills** • Network Technology Skills • M2M Communication Skills • Robotics Skills • Artificial Intelligence Skills • Predictive Maintenance Skills

4.4 Summary

In this chapter, we developed a comprehensive competency model for employees in Industry 4.0. This comprises not only Industry 4.0-specific, but general competencies as well. It considers former research in the areas of Industry 4.0 and competency models as well. The comprehensive competency model for employees in Industry 4.0 was evaluated and enhanced with findings from practice – which were derived from German online job offers.

From taking a closer look at our comprehensive competency model for employees in Industry 4.0, we can conclude that most of the competencies contained in the model are no "new" competencies (except domain knowledge regarding new technological developments). However, the combination, the weighting and the expectation of how much of these competencies an employee should fulfil to what degree are new. We can see a shift from technical experts to technical generalists with an overview of the business. Therefore, it is crucial to provide an adequate education to (future) employees. The future may show if this leads to different Industry 4.0 job profiles that consider how people want to and are able to work as well.

Industry 4.0 comes along with changes in technology, business, work, and society. We can only guess in which direction the world will developed. Therefore, it is not surprising that we do not find too many technological skills, especially in the job offers – and resultantly in the competency model. However, we found a strong need for communication and collaboration skills. We are convinced that economy will need highly qualified technicians in the future. Nevertheless, as the future is uncertain and we expect big changes, it is important that employees learn to communicate and collaborate with people from other professions to be able to understand complex context and correlations in first place and to find and then implement the right technical solutions in second place. Technology will go on changing; employees need the skills to understand what has to be done and the ability to learn the required technologies.

The comprehensive competency model for employees in Industry 4.0 comprises three domain-specific sections. We would recommend revising the section for Engineers, as our focus is – due to our working and project environment – on Business Informatics/IS and Informatics/Computer Sciences. Other domain-specific sections that may be added comprise but are not limited to economics in general – and Industry-specific, e.g., for automotive or banking.

However, our comprehensive competency model for employees in Industry 4.0 can serve as a stable base for further actions in research and practice.

5 A Curriculum for Teaching Relevant Skills and Competencies for Industry 4.0

This chapter answers the second and third RQ:

RQ2: How can competencies for Industry 4.0 be implemented in learning units for (future) employees following best-practice design guidelines?

To answer this RQ, a curriculum for providing skills and competencies for Industry 4.0 is developed based on the former results of this work. Evaluations takes place at several stages of the curriculum development process.

RQ3: Does the proposed prototype curriculum meet the needs of its consumers?

During the development of the prototype Industry 4.0 curriculum, we conducted several iterations of prototyping and testing. As proposed in the Design Thinking approach, we isolated different elements of the curriculum, starting with a draft of the structure over the refined structure to specific elements such as the integration of interactive tools and evaluated them isolatedly (cp. sections 3.3, and especially 3.3.2.4 and 3.3.2.5). All evaluations were conducted with potential customers – but with different participants and in different settings. After each testing, we considered the outcomes. If needed, we changed the items in focus of the evaluation with respect to the customers' feedback. A detailed overview of the evaluations done in the scope of the curriculum development project is given in section 5.2.

5.1 Requirements towards an Industry 4.0 Curriculum

As discussed in section 3.2, challenges in developing innovative and attractive curricula for students and other trainees have risen due to recent technological developments. Especially young learners, who are "digital natives" expect learning to be motivating and an experience. The training needs to catch them – or they will quickly draw their attention e.g., to apps on their mobile devices. Therefore, we concluded that our curriculum should not only contain long slide decks presenting theoretical backgrounds, but a range of interactive elements, such as hands-on exercises, case studies, and other interactive elements.

5.1.1 Personas and Point of Views

In the Define phase, we analysed the results and insights from the focus groups (cp. sections 3.5 and 4.1.2). We developed the two lecturer personas shown in Figure 20 and Figure 21 and the corresponding PoV statements. They represent typical characteristics and needs of the SAP UCCs' customers. By doing so, we discovered that our lecturers have different goals and needs, some of which are opposed. E.g., one lecturer wants to have only guided exercises with detailed descriptions for each step as well as a step-by-step solution for each exercise. Another lecturer wants to go ahead and do advanced programming exercises where his students can come up with different, more complex solutions. At this point, we realized that we had to develop materials at different levels of detail and difficulty and with different degrees of freedom. The following two personas and PoV statements illustrate the conflicting statements:

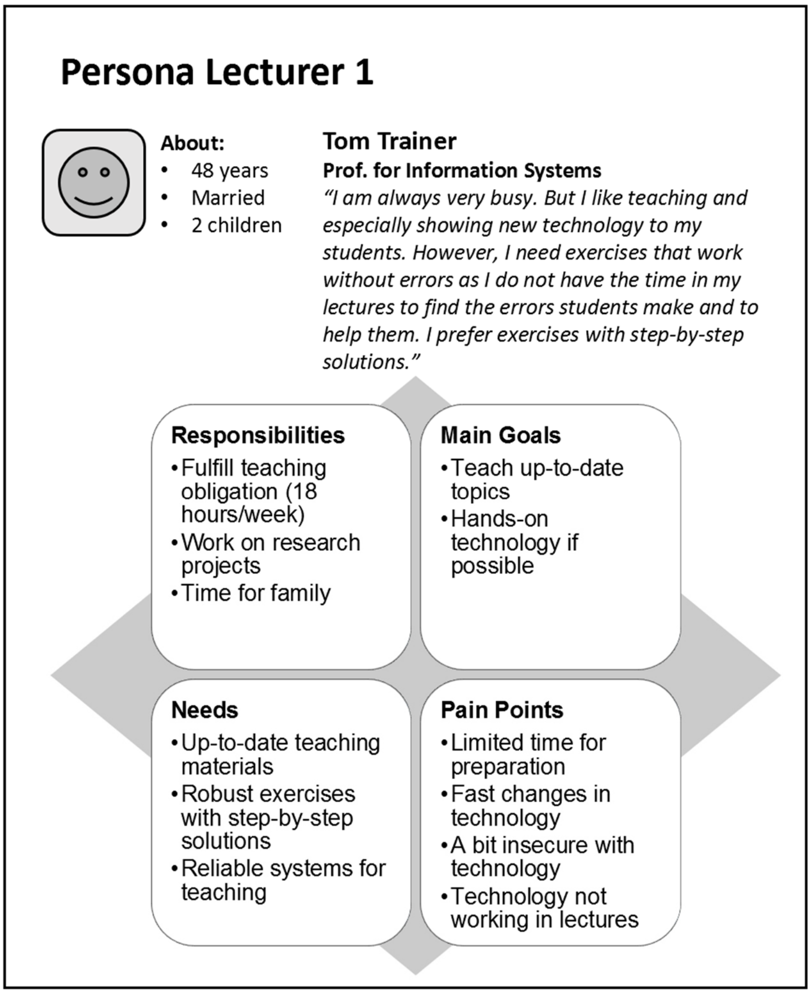

Figure 20: Persona Lecturer 1: Tom Trainer

PoV lecturer 1: *Tom Trainer, an IS lecturer, needs materials and hands-on exercises he can use in his classes. Surprisingly, he becomes very insecure if his students work on hands-on exercises and it comes to mistakes for which he does not find a documented solution in his lecturer notes.*

PoV lecturer 2: *Elvis Excited, an IS lecturer, likes to use hands-on exercises to fortify the knowledge of his students. Although he has to teach eighteen hours a week and needs time for his family as well, he spends many nights on developing his own exercises where his students have to program advanced algorithms and come up with their own solutions that are not provided in his teaching materials.*

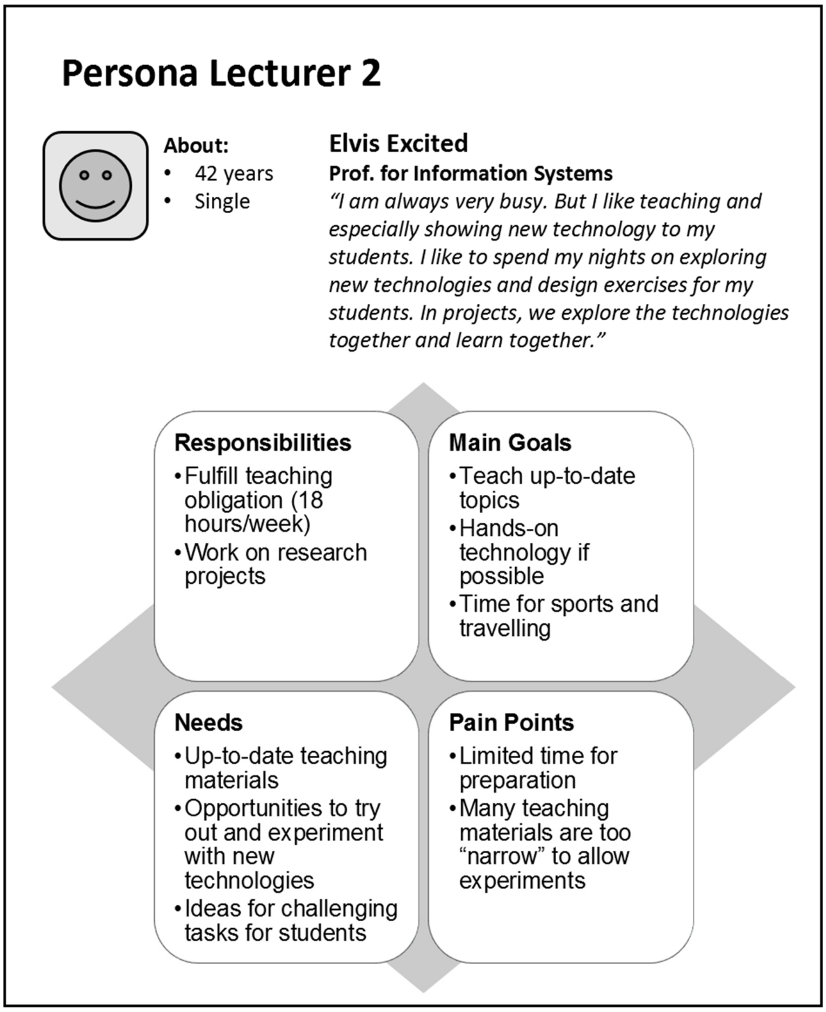

Figure 21: Persona Lecturer 2: Elvis Excited

As we conducted our four focus groups with lecturers, the needs of students or trainees were only marginally considered at this point. However, all of the project team members of curriculum development project teach university classes themselves, using the SAP UCCs' curricula for two to eleven years – and have been studends themselves before. Thus, we created the student persona shown in Figure 22, which represents a student who is attending lecturers in which the "traditional" SAP UCCs' curricula materials are used. We derived the following PoV statement:

PoV student: *Carl Clever, an IS student, wants to do his Master to get a well-paid, interesting job. Although he is really interested in his studies and especially in emerging topics and wants to achieve good grades, he is bored by ex-cathedra teaching which makes it difficult for him to concentrate on the subject instead of chatting with his friends or playing games on his mobile.*

With different personas and PoVs for different groups of stakeholders (lecturers/students) and different opinions in the specific groups (cp. personas and PoVs for lecturers), we made sure to keep all requirements and needs in mind.

Over the past fifteen years, a certain structure for curricula has evolved in the SAP UCCs (cp. section 3.8.1.1): Slides with theory, guided step-by-step exercises, and case studies, both with solutions or online controlling tools for the lecturer. Accompanying, lecturer notes and data sheets containing the main transactions and data were provided. This concept was accepted and used widely by the SAP UCCs' customers. However, we learned from the focus groups and from our own students, that one group of lecturers and especially today's students would prefer to see an increased use of interactive elements. However, another group of lecturers emphasized that they needed detailed solution guides for each hands-on exercise or case study to be able to handle them in classes.

Especially the lecturers expressed that they liked working the virtual company “Global Bike” that is used in most of the SAP UCCs’ curricula. They underlined that they would prefer new scenarios to build on the story of “Global Bike”. Moreover, the lecturers expressed their wish for more flexibility in choosing topics connected to their individual teaching requirements.

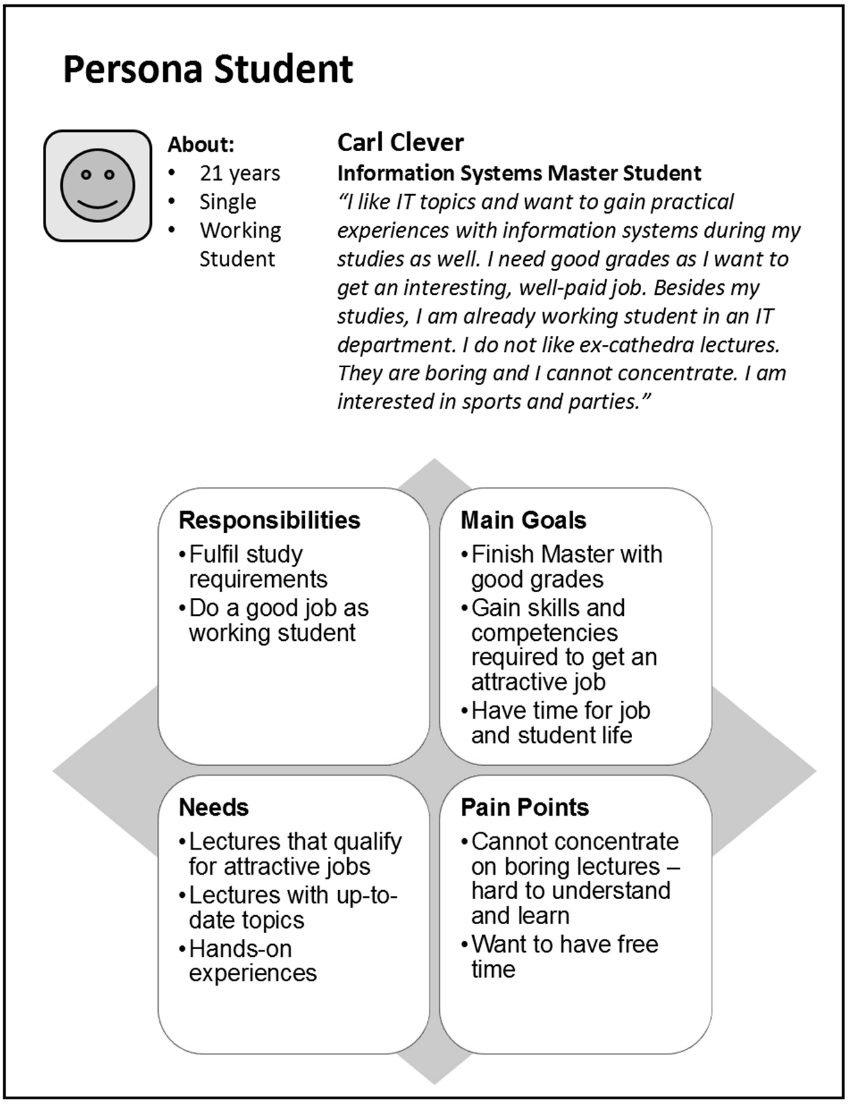

Figure 22: Persona Student: Carl Clever

5.1.2 Skills and Competency Requirements for an Industry 4.0 Curriculum

For skills and competencies that are relevant for an Industry 4.0 curriculum, we refer to the outcome of RQ1, the comprehensive competency model for employees in Industry 4.0, which is presented in section 4.3. The curriculum will not cover all competencies to the same extend, as Industry 4.0 is a wide topic that affects several industries. However, the prototype Industry 4.0 curriculum will rely on the competency model with focus on materials for learners in the areas of Economics, Business Informatics/IS, Computer Sciences/Informatics, and Engineering.

5.1.3 Curriculum Development

Schaper et al. (2012) propose to develop a university curriculum following six phases. We decided to adjust his approach and phases to our project as described in section 2.8. Table 32 gives an overview of where the activities derived from the steps in the six phases are documented. The structure of chapter 5 follows the chronology of the six phases. However, the activities belonging to phase six can be found all over the chapter. We give an overview of evaluation activities in section 5.2 – and and then describe the results together with the corresponding artefacts.

Table 32: Content-Related and Conceptual Steps in Competency-Oriented Curriculum Development (with regards to Schaper et al. (2012, p. 38 f.), cp. section 2.8)

Phase	Content-Related and Conceptual Steps	Implementation Described in Section
1	a) Define qualification goals and the competencies that should be achieved through overall guidelines b) Analyse requirements and needs c) Derive and frame competency profiles	a) 5.1.2, 5.1.4 b) 5.1 c) 5.1.2
2	a) Define learning outcomes and qualification goals using taxonomical criteria and systematics	a) 5.1.4
3	a) Define curriculum modules/learning units of the curriculum with regards to the learning outcome b) Implement curriculum modules/learning units c) Harmonization/evaluation of the curriculum modules/learning units	a) 5.3 and especially 5.3.7 b) 5.5 c) 5.3
4	a) Implement teaching guidelines b) Define workload per curriculum module/learning unit	a) 5.5 b) 5.5
5	a) Develop accompanying measures	a) 5.7, 5.8
6	a) Plan and develop evaluation and quality assurance (QA) mechanisms b) Conduct a pilot session with (parts of) the curriculum modules/learning units c) Revise and optimize	a) 5.2 b) 5.2 c) 5.2, 5.3.2.3, 5.3.4, 5.3.6, 5.3.7, 5.4, 5.5.2, 5.5.2 5.6.2, 5.7.8, 5.8.1.2, 5.8.2.2

5.1.4 Definition of Overall Learning Outcomes for the Prototype Industry 4.0 Curriculum

The project team defined the overall learning outcomes for the prototype curriculum for Industry 4.0 as illustrated in Table 33.

Table 33: Overall Learning Outcomes for the Prototype Industry 4.0 Curriculum (with regards to Prifti, Löffler, and Knigge (2017a))

The Goal of this Curriculum is to Enable Students to…
– *"remember the main terminology and aspects of the [D]igital [T]ransformation* – *understand the basic technological aspects of the [D]igital [T]ransformation* – *apply methods and tools to extract information for the [D]igital [T]ransformation* – *analy[s]e the impact of the [D]igital [T]ransformation on economical, sociological, organizational[,] and technical aspect[s]* – *evaluate the [D]igital [T]ransformation scenarios and aspects with regards to their value for a company* – *create own solutions for different aspects in the context of the [D]igital [T]ransformation"* (Prifti, Löffler, et al., 2017a, p. 3).

5.1.5 Target Groups

Lasi, Fettke, et al. (2014a, 2014b) point out that "the approaches and ideas in the context of "Industry 4.0" are situated at the interface of the disciplines [of] [E]lectrical [E]ngineering, [B]usiness [A]dministration, [C]omputer [S]cience[s], [B]usiness and [I]nformation [S]ystems [E]ngineering, and [M]echanical [E]ngineering as well as the participating segments" (Lasi, Fettke, et al., 2014b, p. 240). As the curriculum development project takes place at the SAP UCC at TUM, the curriculum is added to the offering of the SAP UCCs and therefore addresses the customers of the SAP UCCs. These are institutions of higher education – universities, universities of applied sciences and the like – mainly in the areas of Economics, Business Informatics, IS, Computer Sciences, and Informatics. A second (smaller) target group of the SAP UCCs are schools. However, as we think it is important to have knowledge about "traditional" technologies, workplaces, processes and business models in order to be able to understand the impacts of the digitization and Industry 4.0, we decided to exclude pupils from schools from our main target group. Next, we matched the subjects listed by Lasi, Fettke, et al. (2014a, 2014b) with the customers of the SAP UCCs and the content contained in the curriculum. The prototype Industry 4.0 curriculum covers topics relevant in the areas of **Economics, IS, Business Informatics, Computer Sciences, Informatics, and Engineering**. **Bachelor and master students of these subjects at institutions of higher education are the target group for this curriculum**. Of course, all other customers of the SAP UCCs are invited to use it as well.

5.2 Overview of Evaluation of Curriculum Items

There was no overall evaluation conducted at the end of the curriculum development project and for the whole artefact. However, we did several evaluations for single aspects accompanying the curriculum development project. The evaluation steps are not described in a separate chapter, but always in connection to the description of the development of specific aspects of the curriculum. Table 34 gives an overview of the evaluations conducted during the curriculum development project. For the specific evaluations, findings and implications from them, please go to the sections given in the last column of the Table 34. Evaluation events are described in the following sections.

Table 34: Overview of the Evaluations of Prototypes of Curriculum Items

Subject of Evaluation	Evaluation Time	Evaluation Mode	Findings	Section
First draft of the structure of the curriculum	February 2nd, 2017	Expert Session in Garching bei München[57]	Small remarks, positive feedback in general	5.3.4
Curriculum structure, modular structure, first content	19th June 2017	Pilot	Small remarks, positive feedback in general	5.2.3

[57] The expert session took place on February 2nd, 2017, at TUM in Garching bei München, Germany. Cp. section 5.2.1.

Subject of Evaluation	Evaluation Time	Evaluation Mode	Findings	Section
Final structure of the curriculum/modular structure	September 12th, 2017	"Breakout Sessions"[58]	Average rating of 4.4 out of 5	5.3.6
Sticking to GBI story	September 12th, 2017	"Breakout Sessions"	Average rating of 4.5 out of 5	5.3.2.3
New story: GBS as service provider	September 12th, 2017	"Breakout Sessions"	Average rating of 4.5 out of 5	5.3.2.3
Integration of links to related SAP UA content	September 12th, 2017	"Breakout Sessions"	Average rating of 4.3 out of 5	5.5.2
Integration of links to external content (MOOCs)	September 12th, 2017	"Breakout Sessions"	Average rating of 4.2 out of 5	5.5.2
Learning Journeys for specific topics	September 12th, 2017	"Breakout Sessions"	Average rating of 4.3 out of 5	5.6.2
Curriculum presented in web application	September 12th, 2017	"Breakout Sessions"	Average rating of 4.0 out of 5	5.4.1
Integration of interactive elements, e.g., onlineTED	September 12th, 2017	"Breakout Sessions"	Average rating of 4.3 out of 5	5.7.8
Course Calculator	September 12th, 2017	"Breakout Sessions"	Average rating of 4.1 out of 5	5.7.5
Course Interest Survey	Q1 2018 – Q3 2018	Structured expert interviews	Rated "very useful" for evaluation of own teaching	5.8.1.2
Instructional Materials Motivation Survey	Q1 2018 – Q3 2018	Structured expert interviews	Rated as "less useful" for own teaching, "useful" for evaluation of materials	5.8.2.2

5.2.1 Expert Session "Workshop interaktive Lehre" at TUM in Garching bei München, Germany

On February 2nd, 2017, we conducted the expert session "Workshop interaktive Lehre"[59] at TUM in Garching bei München, Germany, for evaluating the first outcomes of our curriculum development project. Participants of the expert sessions were three university professors from Germany and Switzerland together with eight researchers: Each of the participants was engaged and experienced in university teaching and belonged to the SAP UA community. The overall, modular structure of the curriculum and the concept of the learning journeys were presented and discussed.

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[58] The "breakout sessions" took place in the scope of the 22nd SAP Academic Conference EMEA at September 12th, 2017 in Karlsruhe, Germany. Cp. section 5.2.2.
[59] Workshop interactive teaching. Translated by the author.

5.2.2 *"Breakout Sessions" at the 22nd SAP Academic Conference EMEA 2017 in Karlsruhe, Germany*

The 22nd SAP Academic Conference EMEA 2017 took place in Karlsruhe, Germany[60]. The SAP Academic Conferences are regional annual SAP UA/SAP UCC user group meetings. In the scope of this conference, we conducted two "breakout sessions". The participants were lecturers from the EMEA region – academic customers of the SAP UCCs for different products. Ahead of the sessions, we invited three lecturers to take part in a panel discussion regarding different aspects of the new curriculum in front of the podium. Everyone from the audiences was allowed to take part in the discussion. In the first "breakout session", we had three participants in the panel discussion from the UK, Portugal, and Greece. In the second "breakout session", we had one participant from Finland, and three from Germany. The sessions had between twenty and forty participants. After the panel discussions we asked the audience to fill out a questionnaire. This comprised questions regarding the structure of the curriculum, the learning journeys for specific topics, the Curriculum Navigation Application, the Course Calculator, the integration of interactive online elements such as onlineTED, and the integration of related contend from SAP UC, and external providers (MOOCs) (cp. appendix E). In the first session, we were able to collect 34 replies. In the second session, we collected nine. For further analysis, the sessions were recorded and transcribed.

Three members of the curriculum development project team conducted the "breakout sessions". Before the panel discussion, we started with a short overview of the story of Global Bike, including the new extension of the story. Next, the participants were presented a list of challenges for the Digital Transformation of Global Bike, such as transforming Global Bike from a business-to-business (B2B) to a business-to-customer (B2C) company, transforming the business model and business strategy, building new competencies in the areas of Industry 4.0, transforming the business processes, or introducing the new SAP S/4HANA system. This was followed by the presentation of the goal of the new curriculum (cp. section 5.3.1) and the overall learning outcomes (cp. section 5.1.4).

5.2.3 *Piloting the Curriculum "The Digital Transformation of Global Bike"*

A pilot version of the prototype "The Digital Transformation of Global Bike" was delivered to a group of twenty-nine pilot customers for testing on June 19th, 2017 (cp. email in appendix F.1). The list of pilot customers included participants from Germany (13), Belgium (1), Finland (2), the United Kingdom (UK) (6), Portugal (2), the USA (1), Switzerland (1), Poland (1), Greece (1), and Ireland (1). Five of those customers already tried out the first SAP S/4HANA materials provided by SAP UCC Munich in advance.

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[60] 22nd SAP Academic Conference EMEA: Sep. 11th – 15th, 2017, Karlsruhe, Germany. https://events.sap.com/de/emea-academic-conference/en/home. Accessed on March 20th, 2018.

The curriculum pilot was built on the curriculum structure version presented in section 5.3.6. However, it did not contain content for all modules comprised in this version, as the development of the content was not completed at that point in time. Thus, the pilot curriculum version contained content for the modules highlighted in Figure 23.

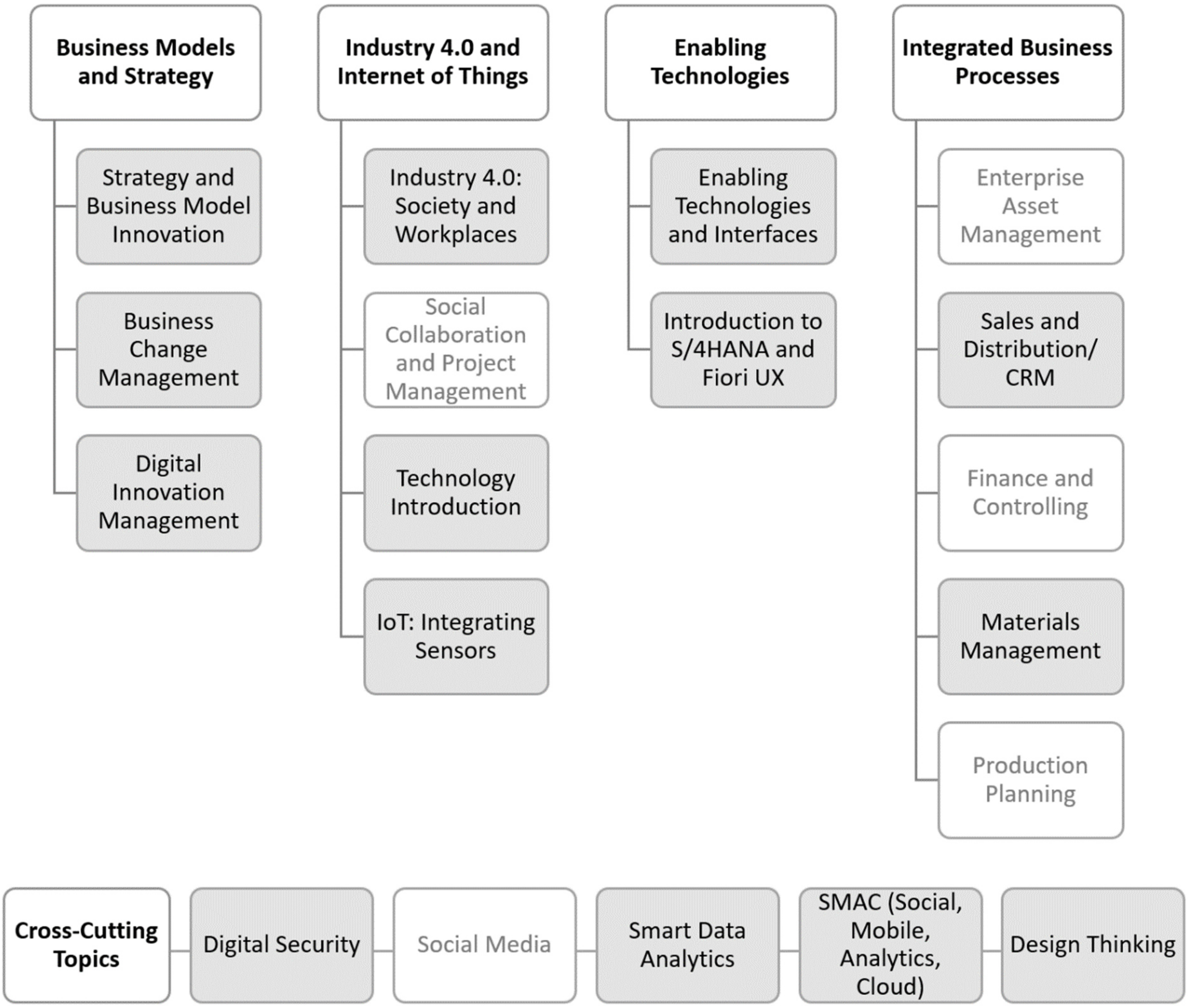


Figure 23: Pilot Version: Content was Provided for the Curriculum Modules Highlighted in this Figure (with regards to SAP UCC Munich: Project Curriculum Development (2016 - 2017))

Two and a half weeks later, an online feedback survey was sent to the pilot customers. It contained questions regarding the layout, materials, content, presentation and navigation structure, etc. (cp. survey in appendix F.2) Some days later, they got a reminder for participation via email. In total, we received eleven answered surveys from Germany (8), Portugal (1), Switzerland (1), and Finland (1). Two lecturers who answered the survey had three to five years of teaching experiences, one had five to ten years, and eight had more than ten years of teaching experience. One was teacher at a school, eight were teaching at universities of applied sciences, and two at universities. One was teaching pupils Economy and Informatics, all others were teaching bachelor students, six were also teaching master students in the subjects of Economics (3), IS (8), Informatics (1), Computer Sciences (2), and Engineering (2). The results of the survey are discussed in the evaluation sections in this chapter.

5.2.4 Course Interest Survey and Instructional Materials Motivation Survey as Means for the Ongoing Evaluation of Curriculum Modules and Materials

The Course Interest Survey (CIS) and the Instructional Materials Motivation Survey (IMMS) are introduced and evaluated in section 5.8 as items of the prototype curriculum. During the productive use of the curriculum, they can serve as means for an ongoing evaluation of curriculum modules and materials when lecturers apply them in class and hand over the results to the SAP UCC who maintains the curriculum and its releases. The CIS collects the participants' feedback regarding their motivation to learn in a specific course – and therefore the outcomes of the survey can be used for a lecturer's class evaluation. The IMMS collects feedback concerning the materials applied in a class – and therefore provides direct insights to the judgements of participants regarding curriculum materials. In the scope of the curriculum development project, the CIS and the IMMS were not used for evaluating new modules or materials of the curriculum yet – but introduced and evaluated as items of the curriculum themselves.

5.3 The Overall Curriculum Structure

Based on the requirements for the prototype Industry 4.0 curriculum, the curriculum development project team developed first ideas and a first prototype for the overall curriculum layout.

5.3.1 Generating Ideas for the Curriculum Structure

In the Ideate phase, we developed the following approaches of how to design the new prototype Industry 4.0 curriculum to address the potential customers' needs:

- **Idea 1:** Stick to the SAP UCCs' "standard" curriculum design and just apply it for Industry 4.0 content. This would especially serve the lecturers who prefer a high level of guidance in technical exercises and those who are already familiar with the "standard" curriculum layout.
- **Idea 2:** Build a new curriculum around a completely new story with no or hardly any connections to previous SAP UCC learning materials. This solution would give the curriculum development project team the maximum degree of freedom, as it would allow tailoring a story to suit the needs exactly.
- **Idea 3:** Build a serious game that covers a range of aspects of Industry 4.0 and includes the advantages of gamification in learning.
- **Idea 4:** Design a curriculum consisting of several modules that mainly sticks or attaches to the story of "Global Bike" to allow lecturers and students to recognize familiar elements. Modules that belong together are organized in sections. However, it should be possible to use the modules independently, so that lecturers could choose a combination of modules – or sections – that fits their requirements. Additionally, offer specific predefined paths through the curriculum using different modules from different sections for specific topics ("learning journeys", cp. section 5.6).

After discussing these ideas in the project team, we concluded that idea 4 would be suited best to cover a wide range of the requirements of the potential customers. The effort needed to implement and maintain such a solution seemed to be practicable. Moreover, the implementation of idea 4 would allow us to integrate the core of idea 1, while allowing us to go ahead and add new content using different kinds of methods and media as well to present new content and new technologies. We decided to build the story of the new curriculum “The Digital Transformation of Global Bike” on the Digital Transformation of the virtual company “Global Bike”, which is already known by many of the potential customers. This allows them to recognize elements if they use other materials provided by the SAP UCCs as well – and therefore to more easily identify with and access the content.

The SAP UCCs provided modular curricula before. In some cases, the modules of those tended to build on one another. The project team decided, that it should be possible to use the modules of the new curriculum independently and without following a specific order. The team decided that each module should contain a wide range of different training materials – from slide decks over guided exercises and case studies to self-learning materials such as videos. The content should be provided on different levels of difficulty and detail, e.g., a slide deck for an overview of smart data analytics, then further slides dealing with different algorithms, hands-on exercises in more detail, and – if possible – expert topics.

The topic Industry 4.0 is a very wide field and it was clear that a large amount of content had to be implemented with limited resources. On the one hand, the project team noticed, that content for some topics already existed in the SAP UA context. On the other hand, they realized that also freely available content such as MOOCs from different providers was available. Thus, they decided to integrate content from SAP UA and external providers, as long as it was a) available for a longer period of times (years) and b) freely available to the potential customer group for the curriculum: institutions of (higher) education which are members of the SAP UA programme.

Based on these decisions, the curriculum goal was defined as follows:

> *“**Curriculum Goal:** The curriculum addresses the **challenges of the [D]igital [T]ransformation**, based on the **example of Global Bike**. It offers various modules for each aspect of the company that is affected by the [D]igital [T]ransformation. The curriculum is **competency[-]based** and each modules addresses specific competenc[i]es for the [D]igital [T]ransformation. It aims at preparing the students to be best qualified as the workforce of tomorrow.”* (Prifti, Löffler, Knigge, 2017b, p. 4)

With these first results, the project team decided to move on to the Prototype phase and then to evaluate the concept draft with potential customers – before starting any implementation and development of content. This would allow stepping back and starting over again at very low costs.

5.3.2 Enhancements to the Story of Global Bike

The project team decided to stick to the story of Global Bike and to extend it in a way that allows to demonstrate the Digital Transformation of the bicycle producing and selling company Global Bike to a PSS provider. The enhanced story is presented section 5.3.2.1, the PSS bicycle in section 5.3.2.2.

5.3.2.1 The Digital Transformation of Global Bike

With the emerge of new technologies, the company Global Bike decided to launch a new line of products; IoT-E-bikes with sensors. Although the customers of Global Bike were interested in the new products, they hesitated to buy them, partly because they had to be offered at high prices. The company managers decided to stick to the IoT-E-Bike, but to offer them as rental city bicycles instead of selling them. (Prifti, Löffler, et al., 2017a).

This idea implies the implementation of a new, service-oriented business model. Therefore, Global Bike founded "Global Bike Sharing" (GBS) as PSS provider for the bike sharing business. This includes the implementation of a new business strategy and a new business model, as well as building up new competencies in different areas such as "change management, digital innovation management, […] IoT and big data technologies. The company also has to invest in IT security as well as in […] topics [such] as social media and collaboration […]." (Prifti, Löffler, et al., 2017a, p. 2). The management of Global Bike concluded that the traditional SAP ERP system used in the Global Bike enterprise did not fulfil the needs of a PSS provider company and that it especially had weaknesses in the area of smart data analytics. Due to the context of the curriculum development project, GBS builds on SAP SE's Industry 4.0-ready ERP solution, SAP S/4HANA.

5.3.2.2 The PSS bicycle

With regards to the E-Bike that is described as PSS in the context of the Collaborative Research Center 768[61], the project team defined a range of sensors that are adjusted to the IoT-E-Bike, which GBS wants to rent out. The sensors of the GBS IoT-E-Bike are listed in Table 33.

Table 35: Data Input Sensors of the PSS bicycle rented out by GBS (with regards to Prifti, Löffler, et al. (2017a))

Data Input Sensors of the PSS bicycle rented out by GBS	
Health Sensors	– Heart rate sensor – Muscle oxygen sensor
Environmental Sensors	– Temperature – Humidity – Air pollution

[61] CRC 768/SFB 768: Collaborative Research Center (CRC) 768: Managing Cycles in Innovation Processes – Integrated Development of Product-Service Systems Based on Technical Products. http://www.sfb768.tum.de/en/home/. Sonderforschungsbereich (SFB) 768: Zyklenmanagement von Innovationsprozessen – verzahnte Entwicklung von Leistungsbündeln auf Basis technischer Produkte. http://www.sfb768.tum.de/startseite/.

Data Input Sensors of the PSS bicycle rented out by GBS	
Product Sensors	− Battery charge − Battery health − Air pressure in wheels − Wheel status − Motor status − Brake status
Pedalling Sensors	− Brake usage − Saddle positioning, pressure, usage − Wheel pressure, reaction − Battery charging
Safety Sensors	− Vicinity to vehicles/pedestrians
GPS Sensors	− GPS data − Access to tourism and traffic data

The GBS IoT bicycle collects the data generated with these sensors. This can be subject to different smart data analytic scenarios and can be found for example in the curriculum module "IoT. Integrating Sensors" (Prifti, 2017, p. 41 f.). Possible examples are listed in Table 36.

Table 36: Data Scenarios of the PSS bicycle rented out by GBS (with regards to Prifti, Löffler, et al. (2017a))

Data Scenarios of the PSS bicycle rented out by GBS	
Data from Health Sensors + **GPS Data**	**Fitness Information** − Consumed calories − General fitness − Recommendations for activities
Data from Environmental Sensors + **GPS Data** + **Tourism Data**	**Touristic/Shopping Information** − Alternative routes (by pollution) − Touristic suggestions − Touristic plan − Shopping suggestions
Data from Safety Sensors + **GPS Data** + **Traffic Data**	**Traffic Information** − Alternative routes (in case of traffic) − Alert if close to a vehicle − Contact information in case of an accident
Data from Product Sensors	**Product Information I** − Alerts to recharge battery − Alerts in case of maintenance needed − Identification of fleet problems − Failure analysis
Data from Pedalling Sensors + **Data from Product Sensors**	**Product Information II** − Analysis of how the product is used − Use of results for optimization of design and functionality

5.3.2.3 Evaluation of the Enhancement of the Story of Global Bike

The participants of the expert session (cp. section 5.2.1) rated the idea of sticking to and extending the story of GBI very positive – as it makes it easier for customers of the curriculum as well as for students to identify with the story. In the “breakout sessions” (cp. section 5.2.2), we introduced the new curriculum as well. The fact that we stuck to and extended the well-known story of GBI instead of implementing a completely new story, was rated with 4.5 points out of 5 – a very positive result. This is in line with the results from the survey from the pilot customers (cp. section 5.2.3), which similarly rated keeping the GBI story with 4.5 points out of five.

Next, we introduced the extension of the story in the “breakout sessions” (cp. section 5.2.2) – the new affiliated company of GBI – GBS. The participants rated this story of GBS as a service provider even slightly better, and as well with 4.5 points out of 5 – another very positive result. The pilot customers (cp. section 5.2.3) rated the new story with 4.1 points out of 5. They liked the idea of enhancing the story with a service offering. One participant would prefer to see a scenario where production is digitized, another one made very helpful suggestions for improving the story and the implementation of it in SAP S/4HANA.

5.3.3 First Version of the Overall Curriculum Structure

Based on the outcomes of the Ideate phase, we implemented the first prototype of the curriculum “The Digital Transformation of Global Bike”. The result was an overview draft of different stacks that contained different topics – without any further context, information about future content, or navigation interfaces. This first prototype – just one MS PowerPoint (PPT)-slide – is presented in Figure 24. It consisted of twenty modules which were assigned to the eight sections “Business Model and Strategy”, “Industry 4.0/IoT”, “Enabling Technology”, “Integrated Business Processes”, “Digital Security”, “Social Media”, “Smart Data Analytics”, and “Cross-Learning Units”. Each section combines modules that belong to one superordinate topic. We decided to use these eight sections for the following reasons:

- The section “Business Model and Strategy” contains strategic topics from a business point of view – with no regards to any technical implementation. The topics in this section deal with the questions of what the enterprise does, where it is heading, how, and why. The focus is on business models and strategies that emerge or need to be changed because of the Digital Transformation.
- The section “Industry 4.0/IoT” contains an overview of characteristic aspects of Industry 4.0 such as an overview of technological developments, sensors, but as well collaboration, and the impact of Industry 4.0 on society and workplaces.
- The section “Enabling Technology” contains information on a more detailed and more technical level than “Industry 4.0/IoT”. As we wanted to build our curriculum in the scope of the SAP UCCs, it comprises an introduction to SAP S/4HANA.
- The section “Integrated Business Processes” comprises a deep dive into operational business processes, shown at the example of SAP S/4HANA.
- The section “Digital Security” covers topics connected with the security of personal and business data regarding the strong use of the internet and networks in Industry 4.0. The goal is to awake awareness for typical risks in an Industry 4.0 environment.

- The section “Social Media” deals with the increasing use of social media by companies regarding direct contact to customers and employees, but as well as marketing and research channel.
- The section “Smart Data Analytics” was added as big data and smart data are two of the main components of Industry 4.0. Dealing with huge amounts of data, building analytics and draw the right conclusions for business is quite a complex, comprehensive field. This section addresses especially data analysts and data scientists.
- The section “Cross-Learning Units” contains topics that are connected to several of the aforementioned sections.

The topics are grouped into the sections in a way that customers who want to focus on technical aspects may choose special sections, while other sections address business process users or strategic topics. In a way, each section can be understood as introduction to one superordinate topic. Besides the sections, we planned to offer a second way to enter the curriculum: a collection of modules for specific topics – without regards to the superordinate sections – plus the possibility to go ahead, to make a deep dive into those topics. Therefore, we added “learning journeys” – pre-defined paths that lead through the curriculum concerning specific topics (cp. section 5.6). We presented and discussed the idea of these learning journeys in the evaluation sessions (cp. section 5.2). As the feedback was positive, we implemented the learning journeys – after providing content for the modules and sections. In general, the sections contain introductions to specific topics while the learning journey connect topics from different sections and go ahead as they contain links to additional external content for deep dives or special topics.

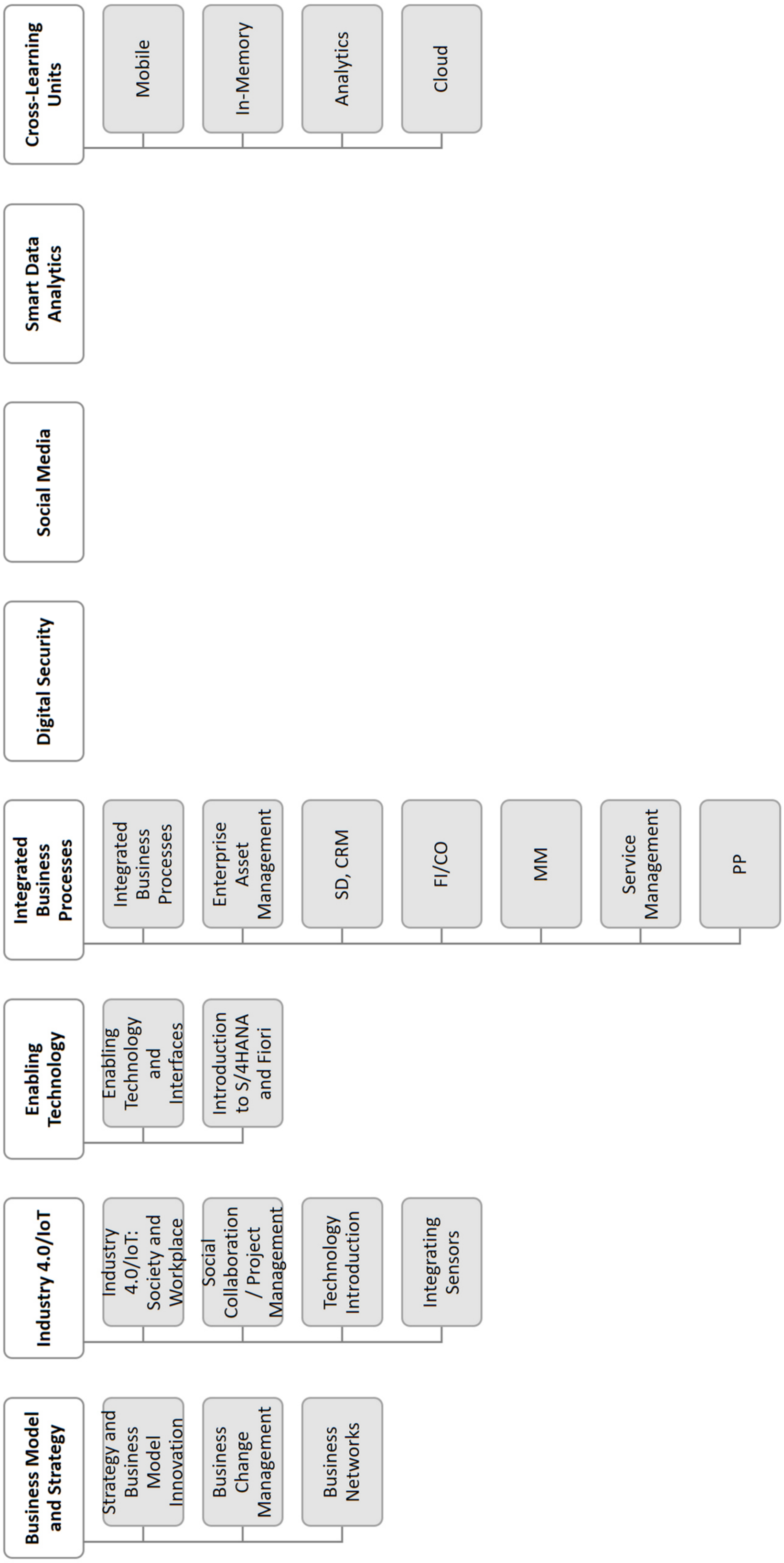


Figure 24: First Draft of Curriculum Layout (with regards to SAP UCC Munich: Project Curriculum Development (2016 - 2017))

Together with a short explanation, this prototype was adequate and sufficient to visualize our idea of a modular-built curriculum. The explanation contained the information that the curriculum would consist of independent modules. Thus, consumers can choose which modules they want to use and what topics they want to focus on. The modules contain learning materials for defined topics in different levels of difficulty and detail concerning the needs of the different target groups on the one hand, and different levels of pre-knowledge on the other hand. The intention of using this curriculum is not that it matches exact to one term or lecture – it rather offers building blocks, which can be combined by each lecturer to form an individual lecture – or a training for further education.

As the new curriculum "The Digital Transformation of Global Bike" was developed in the scope of the SAP UCC at TUM in Garching bei München, Germany, the goal was to sell it to the SAP UCC's customers. The regional SAP Academic Conferences are the user group meetings of the SAP UA members and SAP UCC customers. Thus, we decided to place a first teaser for the upcoming curriculum at the 21st SAP Academic Conference EMEA 2016[62], in Potsdam, Germany. We created a flyer with the first draft of the overall structure of the curriculum, some basic information, and a call to participate in the further curriculum development as pilot customer. While preparing the flyer, we discovered some inconsistencies in the first draft of the overall curriculum layout: The topics of "Digital Security", "Social Media", and "Smart Data Analytics" were connected with several other modules – and especially with the "Cross-Learning Units". Thus, we decided to change the structure of the curriculum – which resulted in the second version, presented in section 5.3.4.

5.3.4 Second Version of the Overall Curriculum Structure and its Evaluation

The second version of the overall curriculum structure is presented in Figure 25. This version was presented in a flyer together with additional information and the call to participate in the further curriculum development as pilot customer to the prospective users at the 21st SAP Academic Conference EMEA 2016 in Potsdam, Germany (Knigge (2016), cp. appendix G).

The eight sections were restructured to five remaining sections. "Digital Security", "Social Media" and "Analytics" were added to the section "Cross-Cutting Topics" as they share the characteristic that they touch several of the other sections. Thus, all aspects from "SMAC" – "Social", "Mobile", "Analytics", and "Cloud", were united in one section now. Moreover, the curriculum structure became more compact with these changes. During the further development and evaluations, these sections became cemented as foundation of the curriculum.

[62] 21st SAP Academic Conference EMEA: Sep. 5th – 9th, 2016, Potsdam, Germany. https://events.sap.com/sap-academic-conference-emea-2016/en/home. Accessed on March 20th, 2018.

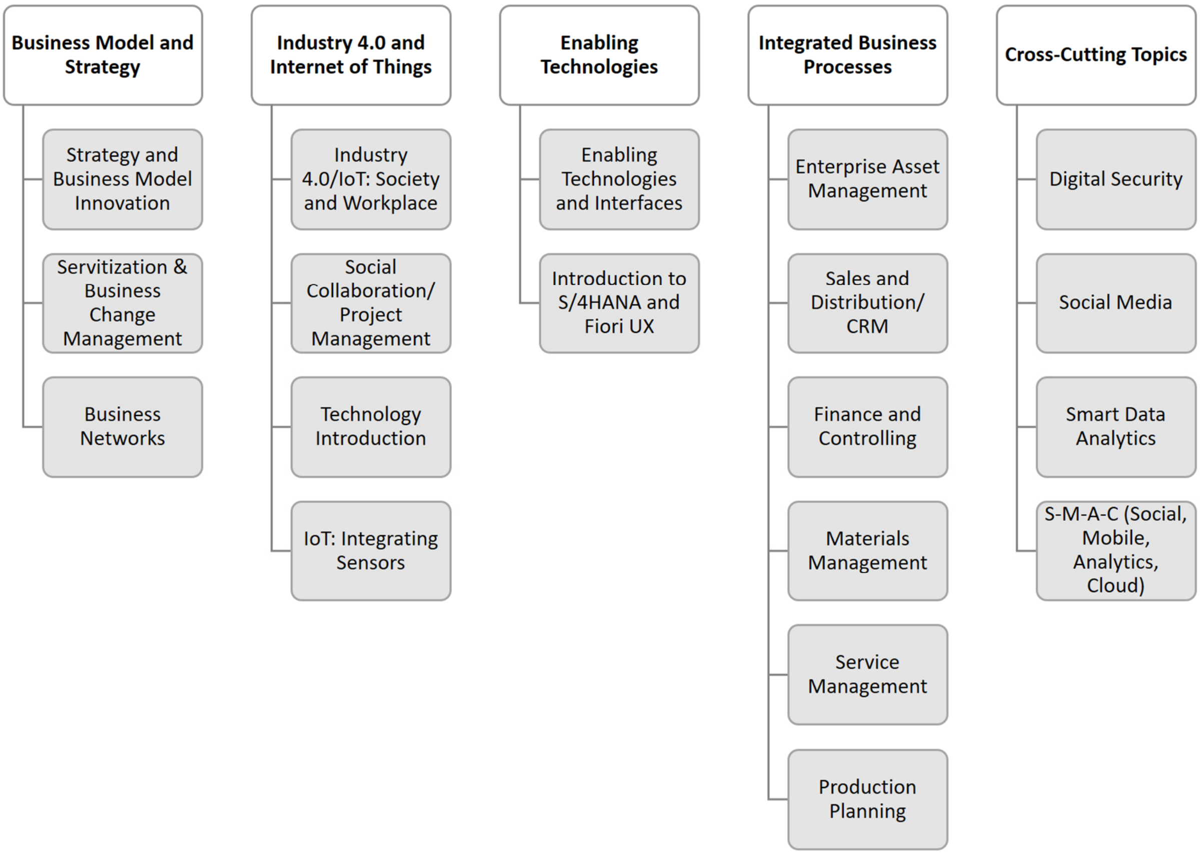


Figure 25: Second Version: Curriculum Modules (with regards to SAP UCC Munich: Project Curriculum Development (2016 - 2017))

Next, this second prototype of the overall curriculum structure was presented to the expert session described in section 5.2.1 on February 2nd, 2017, at TUM in Garching bei München, Germany. In the following discussion, everyone agreed on the structure of the prototype and the modules proposed. One remark stated that the prototype looked too much like a hierarchical organization chart. Further topics for future releases were proposed: master data/master data management, processes/process design and representations, process modelling in SAP S/4HANA, customer-centric business processes, emerging technologies such as blockchain, cognitive computing, and cognitive bots. The participants would like to have access to real-world scenarios in teaching and training. In total, the experts encouraged the project team to proceed with the approach presented.

5.3.5 Third Version of the Overall Curriculum Structure

The third version of the overall curriculum structure is presented in Figure 26. Changes from the previous version to this one result from findings that arose while the content of the curriculum modules was developed. The feedback of the expert session described in section 5.3.2 – especially the remark that the prototype looked too much like a hierarchical organization chart, was not considered at this moment. This version was not subject to external evaluation – but presents an internal in-between draft version.

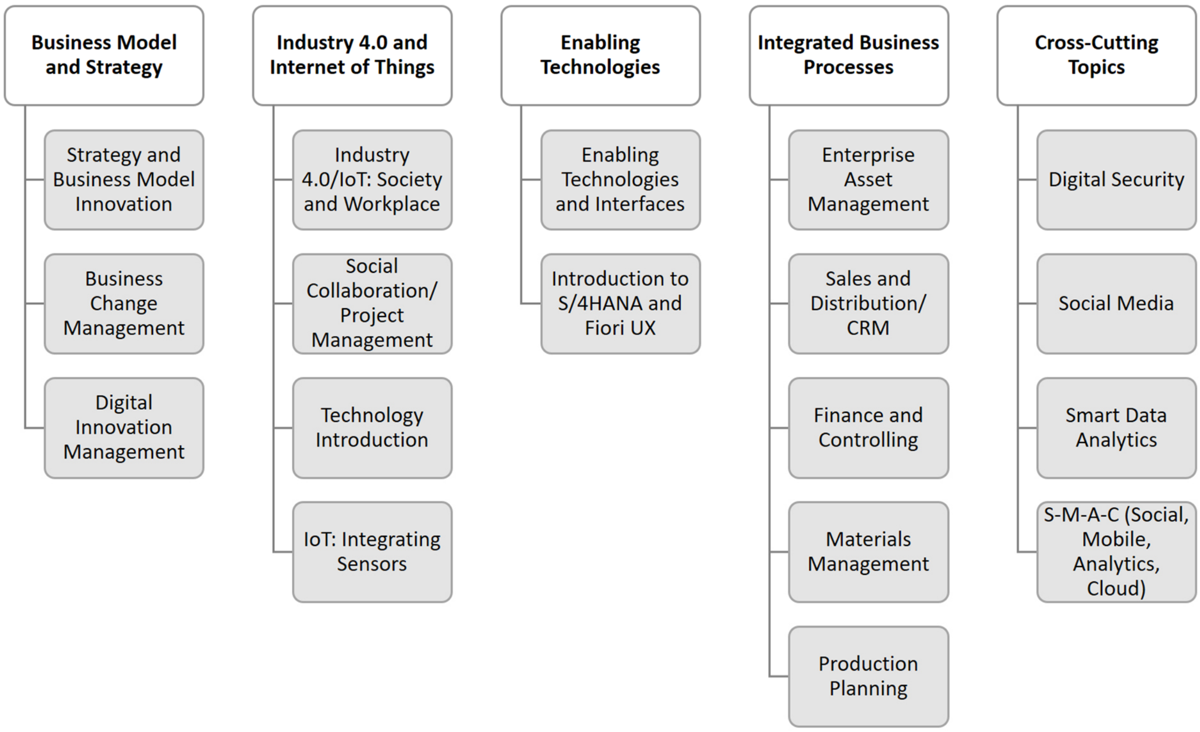


Figure 26: Third Version: Curriculum Modules (with regards to SAP UCC Munich: Project Curriculum Development (2016 - 2017))

5.3.6 Pilot of the Overall Curriculum Structure

The pilot version of the curriculum structure is similar to the third version (cp. section 5.3.5). The only difference is that we changed the structure in order to avoid the similarities to a hierarchical organizational structure – as criticized in the expert session (cp. section 5.2.1). With this result, we have the four sections of "Business Models and Strategy" (strategic topics), "Industry 4.0 and Internet of Things" (technological topics, overview, impacts of Industry 4.0), "Enabling Technologies" (deep dive into technology), and "Integrated Business Processes" (operative) as columns – each of those connected with the section of "Cross-Cutting Topics". The pilot version is shown in Figure 27.

This version of the curriculum structure was evaluated in the piloting session described in section 5.2.3. The pilot customers rated the idea of a modular-built curriculum with 4.4 points out of five. One wishes for more integration between the modules in the section "Integrated Business Processes". However, this may cause conflicts when combining it with the idea of a curriculum of modules that can be used independently.

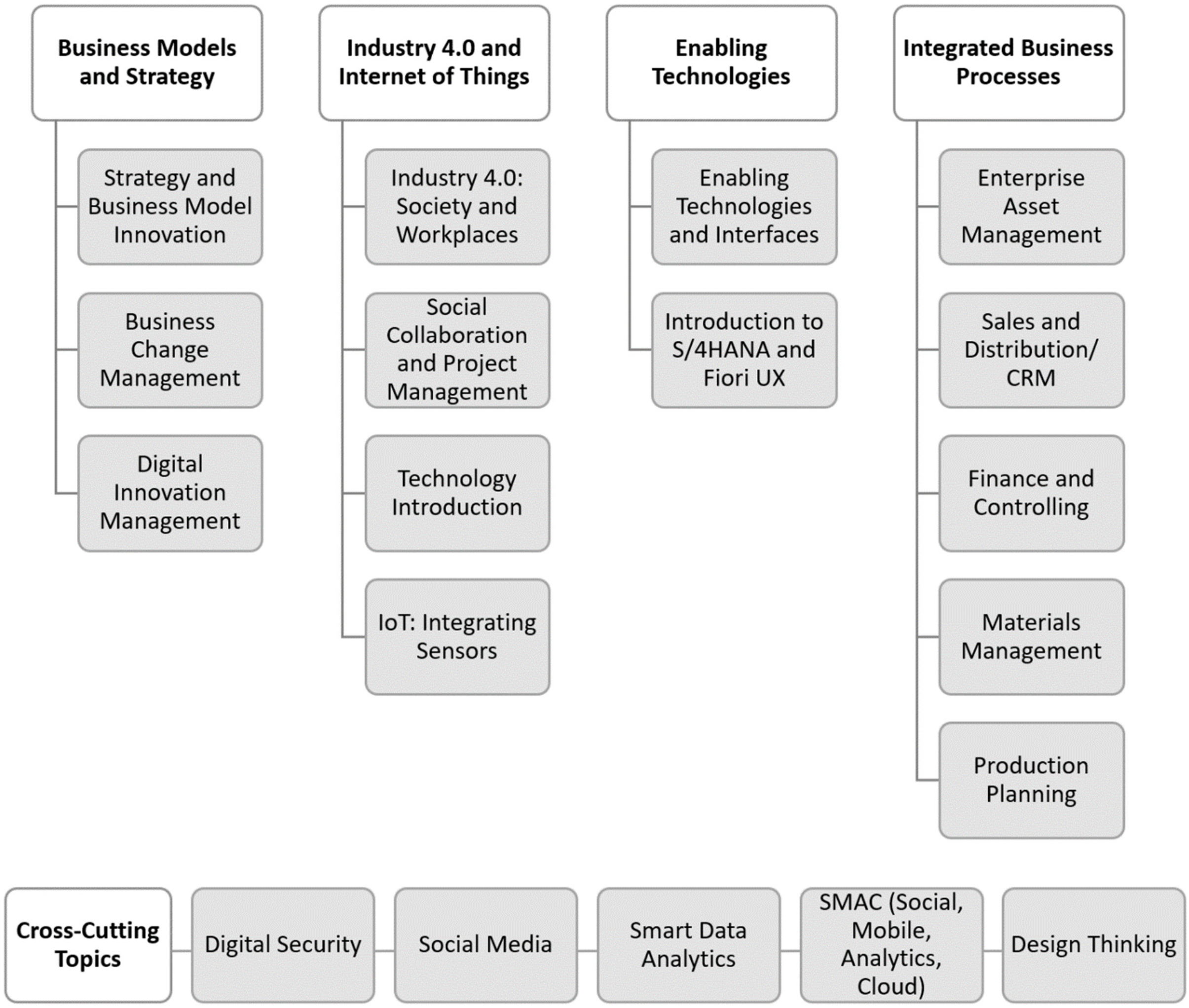


Figure 27: Pilot Version: Curriculum Modules (with regards to SAP UCC Munich: Project Curriculum Development (2016 - 2017))

5.3.7 Final Version of the Curriculum Structure and its Evaluation

We further adjusted the arrangement of the modules – as well as some of the names and wording due to the feedback from the expert session– or because it appeared, that these changes would make the modules more consistent while we were working on the content of the specific modules. The resulting curriculum structure is presented in Figure 28.

This last version of the structure of the curriculum "The Digital Transformation of Global Bike" contains the sections "Business Models and Strategy", "Industry 4.0 and Internet of Things", "Enabling Technologies", and "Integrated Business Processes". Additionally, it contains the section "Cross-Cutting Topics" that comprises topics that may touch one or several modules of the formerly listed sections. These sections contain nineteen modules in total.

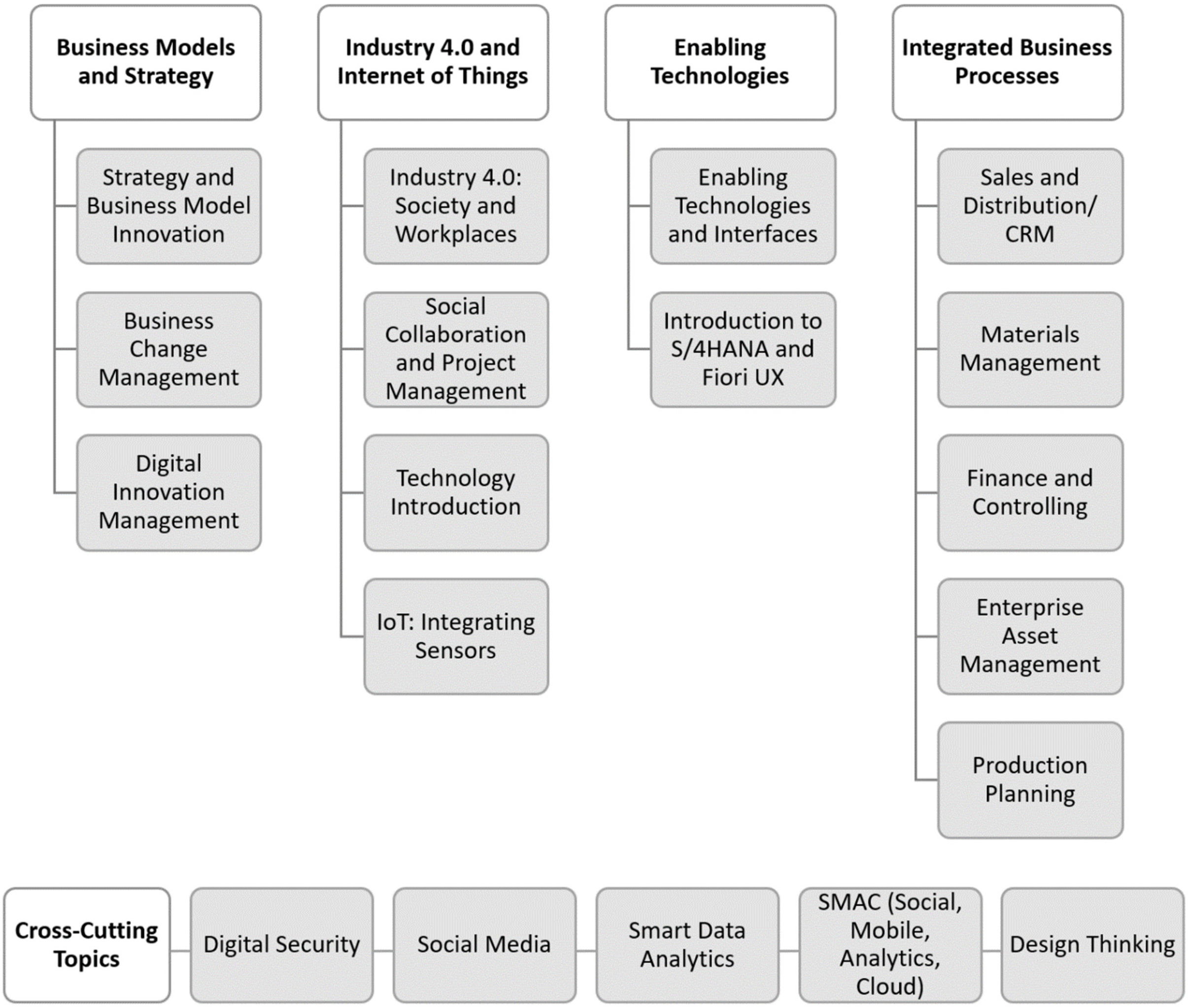


Figure 28: Final Structure of Curriculum Sections and Modules (with regards to Knigge (2016))

To facilitate the switch from the previous GBI curricula to the curriculum “The Digital Transformation of Global Bike”, we added the modules overview to the landing page of the new curriculum, which is shown in Figure 29. In the first row, the modules of the GBI curriculum “Introduction to ERP using Global Bike” (SAP UCC Magdeburg, 2017), which makes use of the “traditional” SAP ERP system, are shown. The “traditional” GBI curriculum contains fourteen modules plus two additional materials as shown in the first column of Table 37. The illustration shown in Figure 29 gives users of the “traditional” curriculum “Introduction to ERP using Global Bike” a quick overview of where they can find topics and materials in the new curriculum. The second column of Table 36 connects the new content to the corresponding old materials. The topics HCM/HR, WM, and QM are not implemented in the current version of the Industry 4.0 curriculum “The Digital Transformation of Global Bike”. They may be added in a future release.

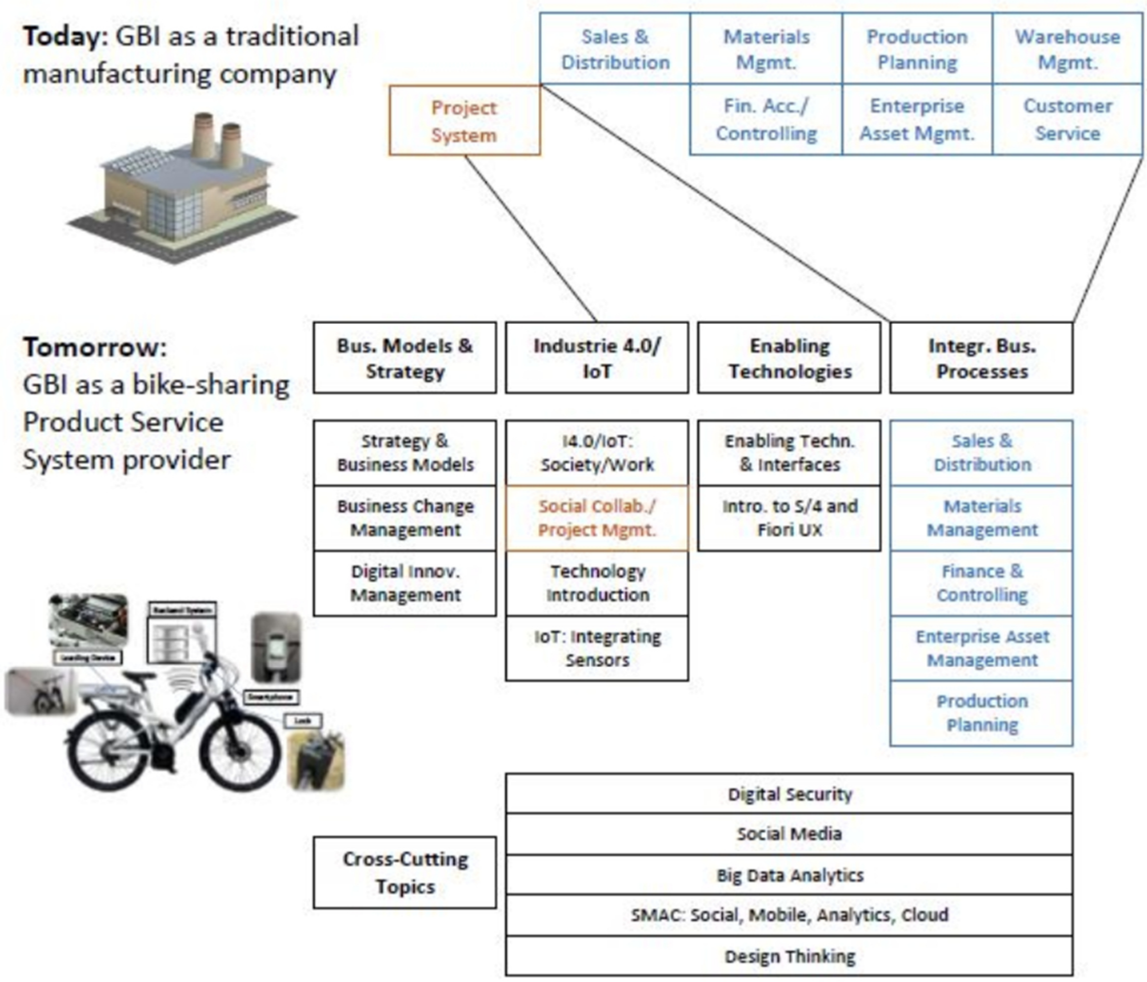


Figure 29: From Global Bike Inc. to Global Bike Services (screenshot from curriculum "The Digital Transformation of Global Bike", provided by the SAP UCC Munich: Project Curriculum Development (2016 - 2017))

Table 37: Modules of the "Traditional" Curriculum "Introduction to ERP using Global Bike, version 3.1" and Corresponding Modules of the Industry 4.0 Curriculum "The Digital Transformation of Global Bike" (with regards to SAP UCC Magdeburg (2017) and SAP UCC Munich: Project Curriculum Development (2016 - 2017))

Modules of the "Traditional" Curriculum "Introduction to ERP using Global Bike, version 3.1"	Corresponding Modules of the Industry 4.0 Curriculum "The Digital Transformation of Global Bike"
Introduction to SAP	Section "Enabling Technologies", module "Introduction to S/4HANA and Fiori UX"
Navigation in SAP ERP	Section "Enabling Technologies", module "Introduction to S/4HANA and Fiori UX"
Introduction to Global Bike	Included in the landing page and in the lecturer notes of the curriculum (Prifti, Löffler, et al., 2017a; SAP UCC Munich: Project Curriculum Development, 2016 - 2017)

Modules of the "Traditional" Curriculum "Introduction to ERP using Global Bike, version 3.1"	Corresponding Modules of the Industry 4.0 Curriculum "The Digital Transformation of Global Bike"
SAP ERP module Sales and Distribution (SD)	Section "Integrated Business Processes", module "Sales and Distribution/CRM"
SAP ERP module Materials Management (MM)	Section "Integrated Business Processes", module "Materials Management"
SAP ERP module Production Planning (PP)	Section "Integrated Business Processes", module "Production Planning"
SAP ERP module Financial Accounting (FI)	Section "Integrated Business Processes", module "Finance and Controlling"
SAP ERP module Controlling (CO)	Section "Integrated Business Processes", module "Finance and Controlling"
SAP ERP module Human Capital Management (HCM)	
SAP ERP module Warehouse Management (WM)	
SAP ERP module Project System (PS)	Section "Industrie 4.0 and Internet of Things", module "Social Collaboration and Project Management"
SAP ERP module Enterprise Asset Management (EAM)	Section "Integrated Business Processes", module "Enterprise Asset Management"
SAP ERP module Customer System (CS)	Section "Integrated Business Processes", module "Sales and Distribution/CRM"
SAP ERP module Quality Management (QM)	
Cross-Module (additional material)	
Instructor Tools (additional material)	

This final structure of the first release of the prototype curriculum was evaluated in the "breakout sessions" at the 22nd SAP Academic Conference EMEA on September 12th, 2017 in Karlsruhe, Germany (cp. section 5.2.2). The general feedback of the participants from the "breakout sessions" was positive. They rated the modular structure of the curriculum for supporting more flexibility in tailoring their own lectures with 4.4 points out of 5, which is a very positive result. One important aspect from the discussion was that the lecturers would like to have some help in tailoring their courses using the modules. Parts of this demand were already met when we introduced the Course Calculator later in the same sessions (cp. section 5.7.5).

Furthermore, the participants of the "breakout sessions" proposed ideas for additional content, i.e., HR topics and a model concerning the migration from SAP ERP to SAP S/4HANA. One participant expressed his wish for an additional module "Application Development". However, due to limitations in time resources, we decided not to integrate these aspects into the first release of the curriculum, but to add it to a list for possible later releases.

5.4 Curriculum Navigation Application

In order to present the materials of the prototype Industry 4.0 curriculum to the lecturer in a structured way, we implemented a HTML application that guides him on different paths through the materials and the corresponding tools. The technical details are explained in section 3.8.3.3.

The HTML application is structured as follows: All folders that contain the curriculum content are stored in one main folder together with the HTML files “index.html” and “Abbreviation.html” as shown in Figure 30. This main folder can be compressed, e.g., as ZIP file, and then transferred to the customer. If it is downloaded to the customer’s client, it can be decompressed and locally stored. If the customer wants to open the curriculum landing page, he simply has to open the index.html file by double-clicking on it. He does not have to pay further attention to any of the other folders or the contained materials; everything will be available from the landing page. Technically, it would have been possible to store all materials and HTML files that represent the (sub-) pages in the curriculum application directly in the main folder. However, to make the application well arranged from the point of view of human beings (e.g., curriculum developers), the different materials are arranged in corresponding subfolders. They are linked to from the landing page or subordinated pages using HTML commands.

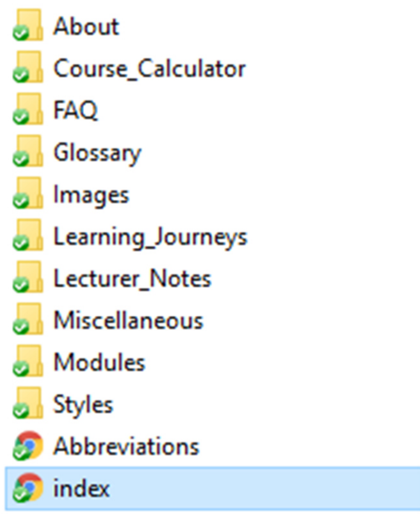
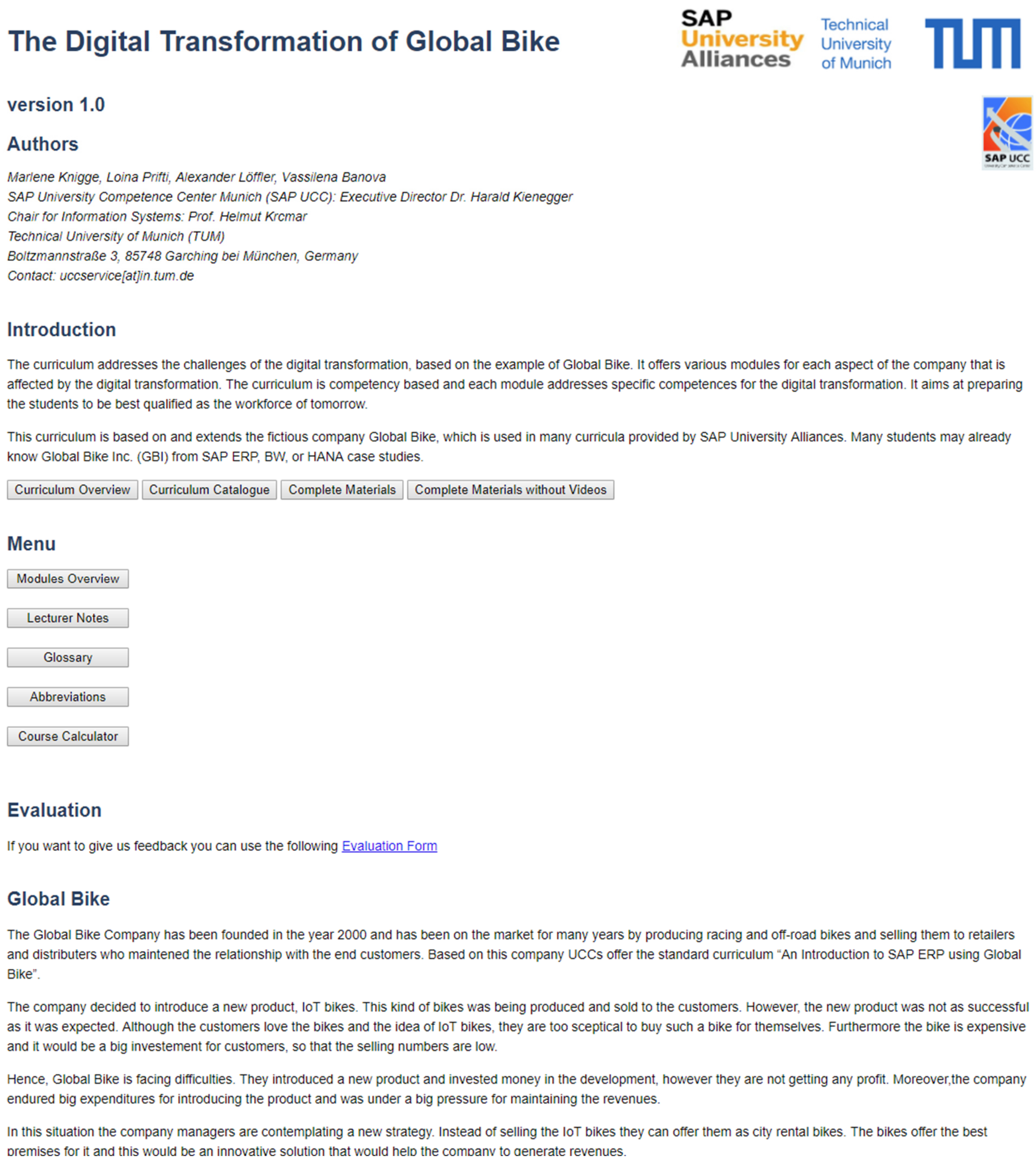


Figure 30: Structure of the Curriculum Navigation Application of the Curriculum "The Digital Transformation of Global Bike" (screenshot from curriculum “The Digital Transformation of Global Bike”, provided by the SAP UCC Munich: Project Curriculum Development (2016 - 2017))

In the first version of the curriculum navigation application, the modules overview shown in section 5.3.6 was implemented into a simple HTML-application as central navigation page for the curriculum. By clicking on one of the modules, the user was redirected to a specific page for the module chosen, which contained all the materials available for this module. At that stage, most of the modules already contained newly created learning materials, hands-on exercises, and further information, such as a collection of SAP UA content and external MOOCs connected to the topic.

The landing page, which is shown in Figure 31 contains overall information of the curriculum “The Digital Transformation of Global Bike”, e.g., concerning authors and partners, quick links to often used subordinated pages and a short introduction to the overall story of the virtual company “Global Bike”. From here, the user can reach all other curriculum items with a maximum of two clicks as illustrated with the navigation tree in Figure 32.



The Digital Transformation of Global Bike

SAP University Alliances
Technical University of Munich

version 1.0

Authors

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Introduction

The curriculum addresses the challenges of the digital transformation, based on the example of Global Bike. It offers various modules for each aspect of the company that is affected by the digital transformation. The curriculum is competency based and each module addresses specific competences for the digital transformation. It aims at preparing the students to be best qualified as the workforce of tomorrow.

This curriculum is based on and extends the fictious company Global Bike, which is used in many curricula provided by SAP University Alliances. Many students may already know Global Bike Inc. (GBI) from SAP ERP, BW, or HANA case studies.

Curriculum Overview | Curriculum Catalogue | Complete Materials | Complete Materials without Videos

Menu

Modules Overview
Lecturer Notes
Glossary
Abbreviations
Course Calculator

Evaluation

If you want to give us feedback you can use the following Evaluation Form

Global Bike

The Global Bike Company has been founded in the year 2000 and has been on the market for many years by producing racing and off-road bikes and selling them to retailers and distributers who maintened the relationship with the end customers. Based on this company UCCs offer the standard curriculum "An Introduction to SAP ERP using Global Bike".

The company decided to introduce a new product, IoT bikes. This kind of bikes was being produced and sold to the customers. However, the new product was not as successful as it was expected. Although the customers love the bikes and the idea of IoT bikes, they are too sceptical to buy such a bike for themselves. Furthermore the bike is expensive and it would be a big investement for customers, so that the selling numbers are low.

Hence, Global Bike is facing difficulties. They introduced a new product and invested money in the development, however they are not getting any profit. Moreover,the company endured big expenditures for introducing the product and was under a big pressure for maintaining the revenues.

In this situation the company managers are contemplating a new strategy. Instead of selling the IoT bikes they can offer them as city rental bikes. The bikes offer the best premises for it and this would be an innovative solution that would help the company to generate revenues.

Figure 31: Landing Page of the Curriculum Application for the Curriculum "Digital Transformation of Global Bike" (screenshot from curriculum "The Digital Transformation of Global Bike", provided by the SAP UCC Munich: Project Curriculum Development (2016 - 2017))

5.4.1 Evaluation of the Curriculum Navigation Application

The first prototype, including the simple HTML-application was presented at the "breakout sessions" describe in section 5.2.2 for evaluation. Most customer liked it, one preferred just to have a ZIP file including all materials. We later integrated ZIP files for all materials of a learning unit or a modul – as well as one for the whole curriculum – in the Curriculum Navigation Application.

The pilot customers (cp. section 5.2.3) rated the general idea of a HTML navigation application with 3.9 points out of 5, and the specific implementation with 3.8 points out of 5. In a possible next release, some time should be invested to enhance the Curriculum Navigation Application – and maybe to redesign its GUI.

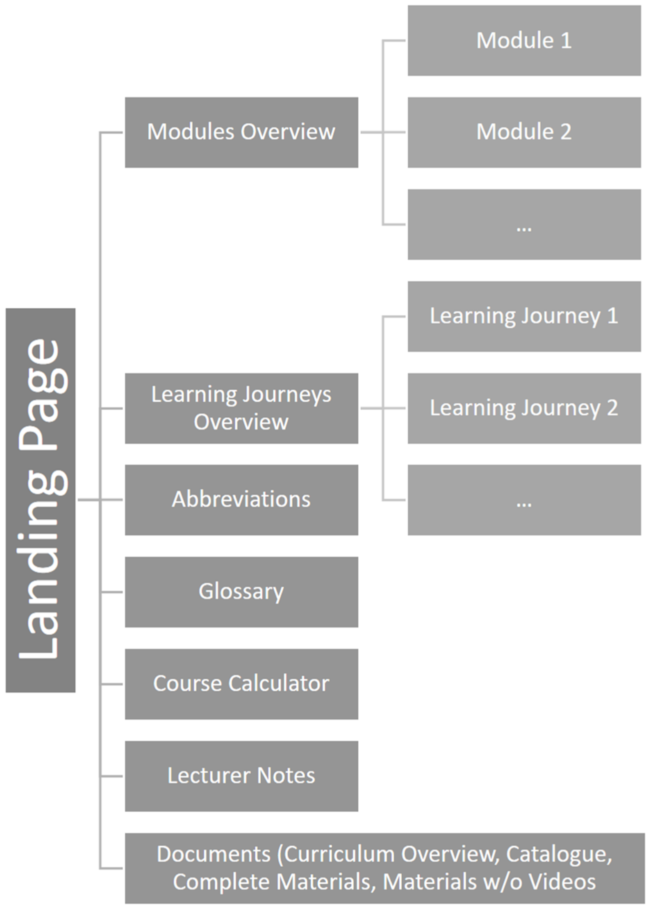

Figure 32: Curriculum Navigation Application: Navigation Tree

5.5 Content for Curriculum Modules

The next step in the curriculum development project was to provide content for the nineteen modules defined before. The goal of the project team was to implement at least one learning unit (LU) for each module with new content specifically tailored for this curriculum. The project team created slide decks relying on scientific literature as far as possible, as well as on hands-on exercises and case studies from scratch. These exercises and case studies mainly build on SAP HANA and SAP S/4HANA. Several of the exercises and case studies can be conducted in teams. This integrates interactivity and experiential learning into the lectures in order to foster competencies such as "teamwork, collaboration, communication, presentation […], problem solving, creativity, etc." (Prifti, Löffler, et al., 2017a).

Additional materials such as videos, and online assessments (cp. section 5.7) were created and added. Some modules, e.g., "Smart Data Analytics", contain several LUs. Moreover, the modules contain links to and short descriptions of additional topic-related materials which are freely available – or accessible in the context of the SAP UA programme. The project team decided to rather integrate already existing materials from the SAP UA programme – instead of implementing redundant materials to avoid confusion among the customers and a higher load of maintenance as well as a higher workload in case of release changes of the underlying software products. Some of these additional materials offer additional introductions to a topic – from other perpectives. Others offer a deep dive into special topics related to the curriculum module. External materials other than from the SAP UA programme comprise MOOCs from the MOOC and E-Learning providers openSAP[63], coursera[64], Alison[65], or Class Central[66]. Our goal was to choose MOOCs which are freely and long-term available.

5.5.1 Detailed Description of the Structure of a Curriculum Module – at the Example of Module "7.0 – Smart Data Analytics"

We illustrate the build-up of a module at the example of the quite comprehensive module "7.0 – Smart Data Analytics". Table 38 gives an overview of the learning objectives of this module defined by the project team. The learning objectives describe **what** should be learned by the participants in this module to **what extend** (e.g., participants "understand" or "are able to apply", …). These learning objectives are followed by the listing of LUs that have been develop explicitly for this curriculum. Table 38 shows that the module "7.0 – Smart Data Analytics" comprises three LUs: "7.0.1 – Hand-on Machine Learning", "7.0.2 – Sentiment Analysis", and "7.0.3 – Sensor Technology and Big Data". LU 7.0.3 is linked to module "2.4 – IoT: Integrating Sensors".The row "Software" contains information about the software that is needed to conduct those LUs.

The section "Related Content" contains the related content for the module at hand, which the project team rated helpful for gaining a first – or deeper – understanding of the topic. For the module "7.0 – Smart Data Analytics", two curricula from the SAP UA programme have been identified: the "Introduction to SAP HANA curriculum" and "Data Mining and SAP HANA". Additionally, three MOOCs from SAP SE's platform openSAP have been rated interesting by the project team: "Enterprise Machine Learning in a Nutshell", "Getting Started with Data Science", and "Text Analytics with SAP HANA".

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[63] openSAP: SAP SE's platform for Massive Open Online Courses (MOOCs): https://open.sap.com/. Accessed on May 22nd, 2018.

[64] coursera: Online platform that provides MOOCs. "Coursera works with universities and other organizations to offer online courses, specializations, and degrees in a variety of subjects, such as [E]ngineering, [H]umanities, [M]edicine, [B]iology, [S]ocial [S]ciences, [M]athematics, [B]usiness, [C]omputer [S]cience, [D]igital [M]arketing, [D]ata [S]cience, and others. Is one of the biggest MOOCs provider worldwide and is based in [the] US." (SAP UCC Munich: Project Curriculum Development, 2016 - 2017). https://www.coursera.org/. Accessed on May 22nd, 2018.

[65] Alison: "[E]-learning provider and academy offering Massive Open Online Courses (MOOCs) to various topics. The majority of Alison's learners are located in the developing world with the fastest growing number of users. It is one of the biggest MOOCs provider outside of the US." (SAP UCC Munich: Project Curriculum Development, 2016 - 2017). https://alison.com. Accessed on May 22nd, 2018.

[66] Class Central: „[O]nline provider of e-learning courses and MOOCs that offers various online courses for free from different universities in the world." (SAP UCC Munich: Project Curriculum Development, 2016 - 2017). https://www.class-central.com/. Accessed on May 22nd, 2018.

Table 38: Module 7.0: "Smart Data Analytics" (with regards to Prifti, Löffler, et al. (2017a))

Section 7: Smart Data Analytics Module 7.0: Smart Data Analytics	
Learning Objectives	After working through the module "Smart Data Analytics", participants… – *"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 [sic!] their own smart data analysis* – *are able to apply their knowledge and extract business value from smart data"* (Prifti, Löffler, et al., 2017a, p. 14).
Curriculum-Specific Content	**Learning Unit 7.0.1: Hands-on Machine Learning** – Introduction Slides – Slides: Text Mining and Sentiment Analysis – Case Study: Sentiment Analysis – Slides: K Nearest Neighbor [sic!] (kNN) – Slides: Naïve Bayes – Case Study: Naïve Bayes – Solution: Naïve Bayes (SAP UCC Munich, 2017z) **Learning Unit 7.0.2: Sentiment Analysis** – Poster: Sentiment Analysis – Video: Sentiment Analysis Training (SAP UCC Munich, 2017aa) **Learning Unit 7.0.3: Sensor Technology and Big Data** – Slides: Data Mining with Sensor Data – Slides: Data Collection with Sensors – Slides: Data Analytics and Reporting with Sensor Data (SAP UCC Munich, 2017c)
Software	*"SAP HANA 1 SPS 12 [sic!], SAP Predictive Analytics 3.2.0" (SAP UCC Munich, 2017z)*
Related Content	
SAP UA	– SAP UA: Introduction to SAP HANA Curriculum – SAP UA: Data Mining and SAP HANA (SAP UCC Munich, 2017y)
External Providers	– openSAP (MOOC): Enterprise Machine Learning in a Nutshell – openSAP (MOOC): Getting Started with Data Science – openSAP (MOOC): Text Analytics with SAP HANA (SAP UCC Munich, 2017y)

Figure 33, Figure 34 Figure 35, and Figure 36 illustrate the representation of the module "7.0 – Smart Data Analytics" in the Curriculum Navigation Application. Figure 33 shows the first part of the module page, which contains the curriculum-specific content – the LUs. Each LU is represented in the same way:

- A short overview of the materials: E.g., for LU "7.0.1 – Hands-on Machine Learning", four slide decks and two case studies are available, two more case studies are announced for one of the next releases.

- The software requisitions are listed: E.g., for LU “7.0.1 – Hands-on Machine Learning”, the following products available at the SAP UCCs are needed: SAP HANA 1 SPS12 and SAP Predictive Analytics 3.2.0.
- A short overview of the content of the module is given.
- The target audience for this LU is named. (SAP UCC Munich, 2017y).

With a click on the title of the LU, the LU itself opens. Figure 34 exemplarily shows the representation of the LU “7.0.1 – Hands-on Machine Learning”. This contains the same information that was already available in the quick-information box on the page of the module as described before. Additionally, this page contains a table which contains all the materials available for this learning unit, including the title of the material, a short description, a classification of the material (e.g., “slide deck”, “case study”, or “solution”), and a direct link for accessing the material. Additionally, each learning unit comprises a link for downloading all content in one ZIP-file. (SAP UCC Munich, 2017z).

Figure 35 shows the second section of the representation page of the module “7.0 – Smart Data Analytics” in the curriculum navigation application – which contains related content from the SAP UA programme. A click on the title of a piece of content redirects the user to the content provisioning platform of SAP UA, the “SAP UA Learning Hub – academic edition”. In addition to other content provided by SAP UA, the materials of the SAP UCCs is available freely here for SAP UA members. (SAP UCC Munich, 2017y). However, customers have to logon to the SAP UA Learning Hub first with their SAP UA accounts. Due to their choice of materials from the SAP UA Learning Hub, customers may need system access to another SAP product provided by the SAP UCCs – where they may have to make a contract and pay an extra fee. Additionally, SAP UA offers further materials on the SAP UA Learning Hub, which is not connected, to the SAP UCCs. However, what is linked from the modules of the curriculum navigation application of the curriculum “The Digital Transformation of Global Bike” is always content provided by the SAP UCCs – on systems provided by the SAP UCCs. At the bottom of this section, a brief information about SAP UA including related links is provided (SAP UCC Munich, 2017y).

The third section of the representation page of the module “7.0 – Smart Data Analytics” is shown in Figure 36. This area contains related content from external providers. Primarily, these are MOOCs, which last from several hours to several weeks. A click on the title of the content redirects the user directly to the content of the external provider. At the bottom of this section, a short overview of all external providers contained in this section as well as related links are given. (SAP UCC Munich, 2017y). To access the MOOCs, it is usually needed to create an account on the platform of the provider. E.g., in the case of openSAP, this is free of charge.

All modules and LUs of the curriculum are represented in a similar way. In case of a module containing only one LU, the landing page of the module contains the LU itself. An overview of the content of the remaining eighteen modules of the curriculum “The Digital Transformation of Global Bike” is given in the following sections.

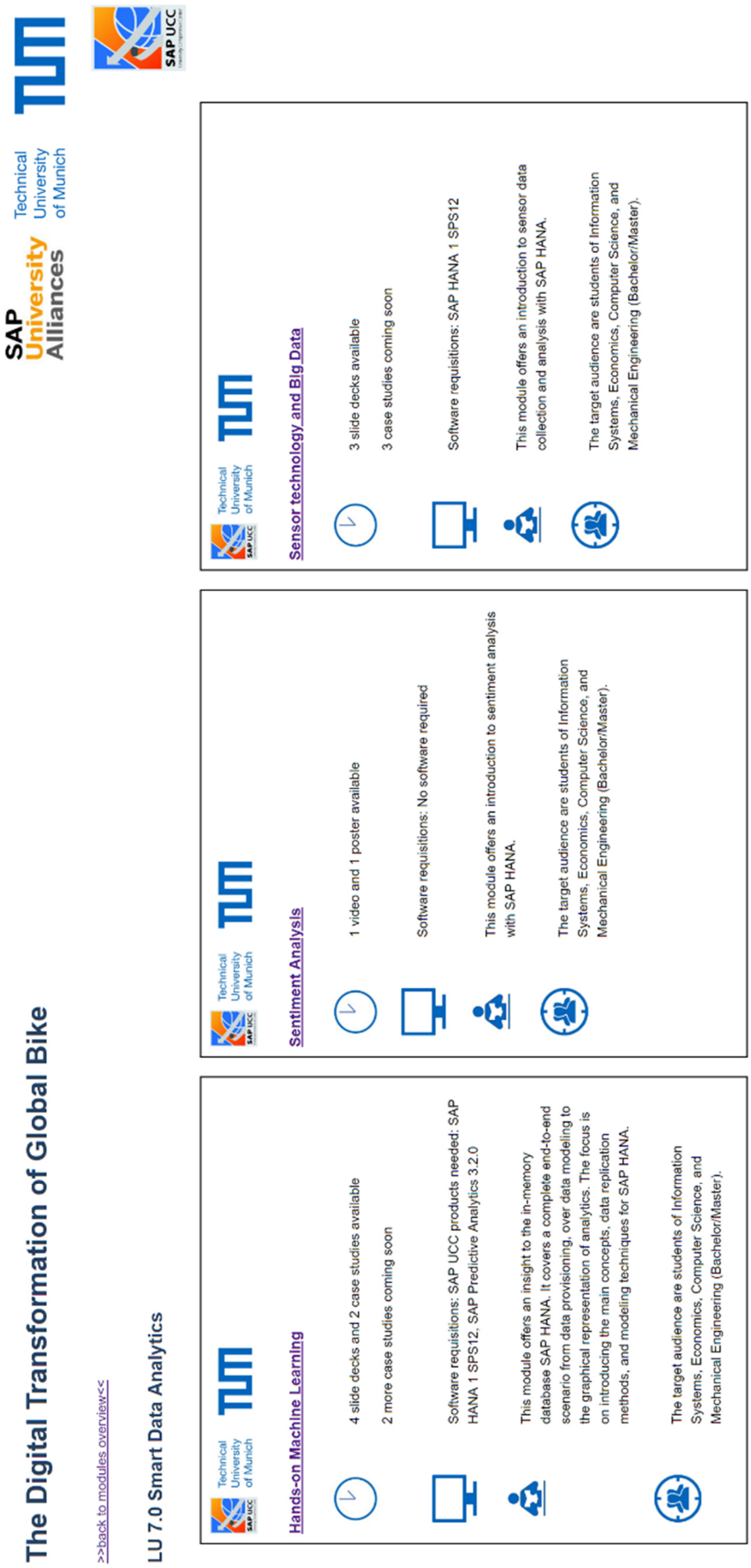


Figure 33: Module 7.0 – Smart Data Analytics – Learning Units (screenshot from SAP UCC Munich (2017y))

Titel	Description	Material	Learning Materials
Introduction Slides	Introduction to Machine Learning	Slide deck	00 Introduction Slides
Text Mining and Sentiment Analysis	Introduction to Text Mining and Sentiment Analysis	Slide deck	01a Intro Text Mining Sentiment Analysis
Sentiment Analysis	Case Study for Sentiment Analysis	Case Study	Sentiment Analysis
K Nearest Neighbor (kNN)	SAP kNN	Slide deck	01d Intro SAP kNN
Naive Bayes	SAP Naive Bayes	Slide deck	01d Intro SAP kNN
Naive Bayes	Case Study for Naive Bayes	Case Study	Naive Bayes
Naive Bayes Solutions	Solutions for Naive Bayes Case Study	Solution	Naive Bayes Solution

Figure 34: Module 7.0 – Smart Data Analytics – Learning Unit 7.0.1 – Hands-on Machine Learning (screenshot from SAP UCC Munich (2017z))

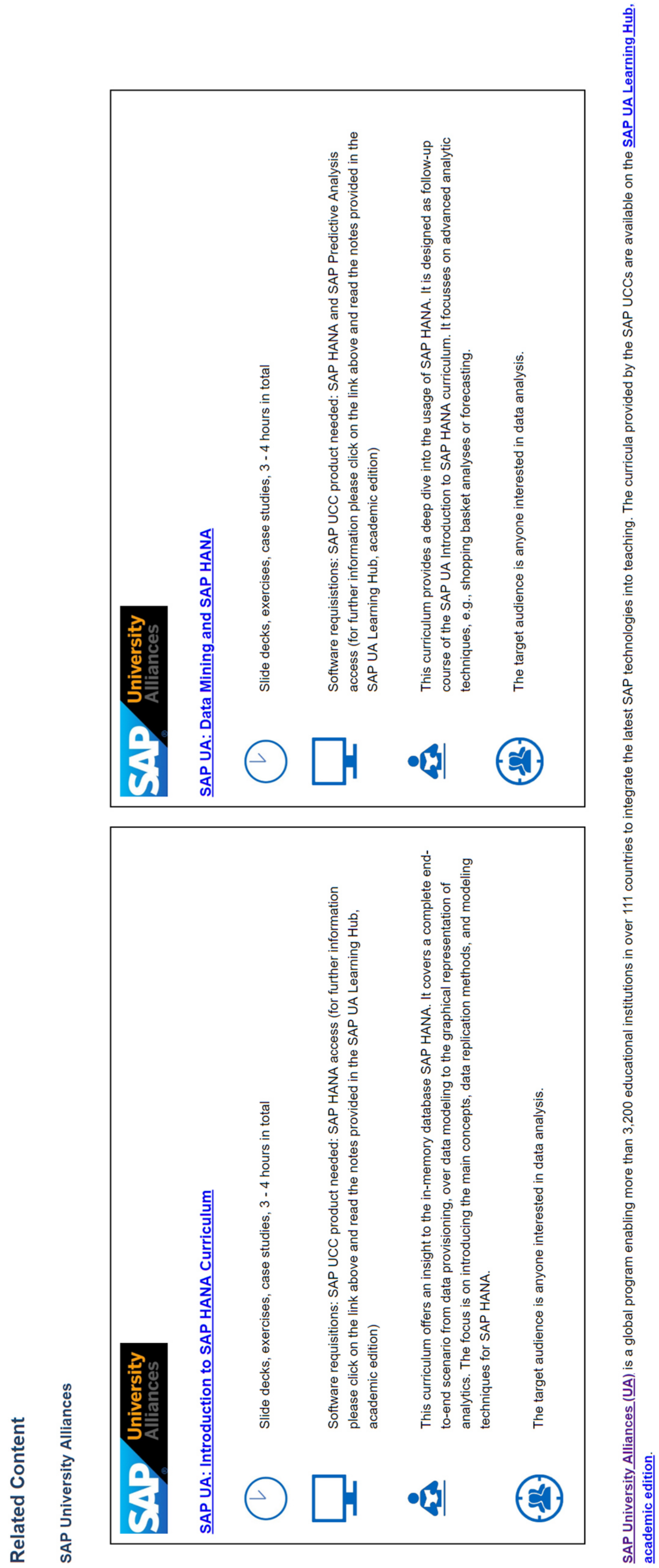


Figure 35: Module 7.0 – Smart Data Analytics – Related Content from the SAP UA Programme (screenshot from SAP UCC Munich (2017y))

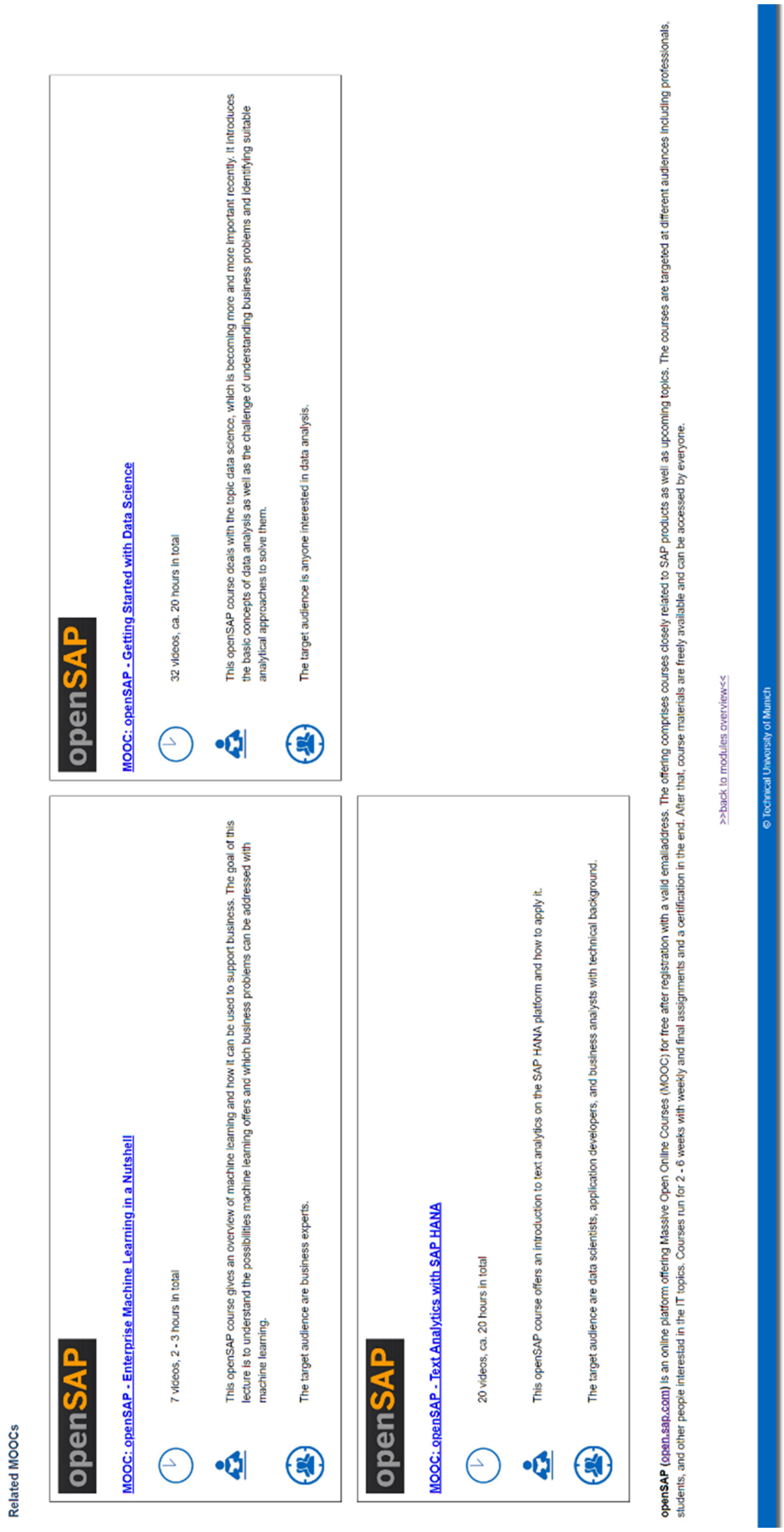


Figure 36: Module 7.0 – Smart Data Analytics – Related Content from External Providers (screenshot from SAP UCC Munich (2017y))

5.5.2 *Evaluation of the Content of the Modules and the Integration of External Materials into the Curriculum Modules*

The pilot customers (cp. section 5.2.3) rated the slide decks provided in the modules with 3.8 points out of 5 in general. As the pilot curriculum did not contain all materials so far, we would expect slightly better results for the first release of the curriculum "The Digital Transformation of Global Bike". However, the goal of the first version was to start with at least some introduction slides for each topic. Thus, there is certainly room for improvement, e.g., for adding more specialized slide decks and deep dives. One lecturer wishes for more background information for the content presented in the slides: In the comments part under the slides, literature advices or podcasts. The pilot customers rated the slides containing the overview of a learning unit ("At the end of this unit, participants…") with 4.3 points out of five.

The pilot customers (cp. section 5.2.3) rated the exercises and case studies in general with 4.3 points out of 5. They evaluated the interrelation between slides and case studies with 4.2 points out of 5. The teaching cases as part of the case studies were rated with 4.3 points out of five. The team/discussion/interaction case studies were rated with 4.1 points out of five. In the pilot version of the curriculum, not all of these elements were already available in their final releases. Thus, we would expect better results if evaluated again on the first release of the curriculum "The Digital Transformation of Global Bike".

The feedback of the pilot customers (cp. section 5.2.3) regarding the usability of the SAP S/4HANA system (3.6 points out of 5), the performance of the system (3.3 points out of 5), and the selection of SAP Fiori UX apps for the case studies (3.6 points out of 5) was moderate. That was probably because the SAP S/4HANA was only shortly available and the SAP UCC as provider was still in the learning process of maintaining, providing and using it on the one hand. On the other hand, the pilot customers did not have any or much experiences with SAP S/4HANA as well. The materials for using the systems (exercises and case studies) were still in an early stage. By now, we would expect the system to run more stable and thus better evaluation results. However, the pilot customers enjoyed the SAP Fiori UX. Exercises and case studies on SAP HANA were not subject to evaluation.

In the "breakout sessions" conducted at the 22nd SAP Academic Conference EMEA 2017 (cp. section 5.2.2), we collected feedback from the participants regarding the integration of related SAP UA content via short descriptions and direct links to the materials. They rated this positive, with 4.3 points out of 5. The pilot customers rated this integration with 4.6 points out of 5.

The integration of links to external content (MOOCs) was evaluated with 4.2 points out of 5 – a positive result as well. The pilot customers (cp. section 5.2.3) rated this integration with 4.4 points out of 5. Some participants from both groups expressed concerns regarding the availability or prices of external MOOCs. However, we focussed on long-term available offerings, which are basically free of charge. One pilot customer gave a hint to another MOOC provider. We included this in the bugs and enhancement list for a possible second release of the curriculum.

5.5.3 Section 1: "Business Models and Strategy"

As shown before, Industry 4.0 will significantly affect business models and business strategies. E.g., a car manufacturer may become a car-sharing provider – which is quite a different business model than manufacturing and selling cars. The first section of the curriculum, "Business Models and Strategy" deals with strategic/management topics from a business point of view – with no regards to the technical implementation. These comprise business models and strategies, business change management, and digital innovation management. A special focus is on business models and strategy emerging or changing in the context of the Digital Transformation. This section contains three modules.

5.5.3.1 Module 1.1: "Strategy and Business Model Innovation"

Module "1.1 – Strategy and Business Model Innovation" offers information about business models and business strategies, including the changes caused by the Digital Transformation that lead to business model innovation, an introduction to e^{3}value, a methodology for developing business models for networked value, or the introduction to the Business Model Canvas. The content of the module is presented in Table 39.

Table 39: Module 1.1: "Business Model and Strategy – Strategy and Business Model Innovation" (with regards to Prifti, Löffler, et al. (2017a))

Section 1: Business Model and Strategy Module 1.1: Strategy and Business Model Innovation	
Learning Objectives	After working through the module "Strategy and Business Model Innovation", participants… – *"understand the fundamentals of business strategies and business models* – *understand the innovation process* – *understand the importance of business model and business strategies in the [D]igital [T]ransformation* – *understand the impact of [digitization] 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"* (Prifti, Löffler, et al., 2017a, p. 6).
Curriculum-Specific 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"* (Prifti, Löffler, et al., 2017a, p. 6 f.)
Software	*"No software required."* (Prifti, Löffler, et al., 2017a, p. 7).

Section 1: Business Model and Strategy **Module 1.1: Strategy and Business Model Innovation**	
Related Content	
SAP UA	None.
External Providers	− openSAP (MOOC): Designing Business Models for the Digital Economy − Coursera (MOOC): Business Strategy − Coursera (MOOC): Digital Business Models − Coursera (MOOC): Business Strategies for Emerging Markets − Coursera (MOOC): Business Model Canvas: A Tool for Entrepreneurs and Innovators (project-centred course) (SAP UCC Munich, 2017m)

5.5.3.2 Module 1.2: "Business Change Management"

Module "1.2 – Business Change Management" offers information and exercises for the topic of business change management – and how to manage changes. Its content is presented in Table 40.

Table 40: Module 1.2: "Business Model and Strategy – Business Change Management" (with regards to Prifti, Löffler, et al. (2017a))

Section 1: Business Model and Strategy **Module 1.2: Business Change Management**	
Learning Objectives	After working through the module "Business Change Management", participants… − *"understand the fundamentals of business change management* − *understand the triggers for business change* − *understand the challenges for business change management in the [D]igital [T]ransformation* − *understand the critical tasks for implementing business change* − *understand the business change management roadmap in the [D]igital [T]ransformation"* (Prifti, Löffler, et al., 2017a, p. 7).
Curriculum-Specific Content	***"Learning Unit 1.2.1: Business Change Management*** − *Introduction Slides* − *Exercise* − *Case Study* (Prifti, Löffler, et al., 2017a, p. 7)
Software	*"No software required."* (Prifti, Löffler, et al., 2017a, p. 7).
Related Content	
SAP UA	None
External Providers	− Alison (MOOC): Introduction to Change Management − Coursera (MOOC): Organizational Analysis − Class Central (MOOC): Managing Changes (SAP UCC Munich, 2017n)

5.5.3.3 Module 1.3: "Digital Innovation Management"

Module "1.3 – Digital Innovation Management" deals with digital innovation management and digital innovation processes. E.g., it provides information about open and closed innovation. It contains several MOOCs, one of those deals with how to apply the Design Thinking approach in innovation processes. The content of the module is presented in Table 41.

Table 41: Module 1.3: "Business Model and Strategy – Digital Innovation Management" (with regards to Prifti, Löffler, et al. (2017a))

Section 1: Business Model and Strategy Module 1.3: Digital Innovation Management	
Learning Objectives	After working through the module "Digital Innovation Management", participants… – *"understand the fundamentals of digital innovation management* – *understand the digital innovation process* – *understand the specifics of the digital innovation for the [D]igital [T]ransformation* – *understand the typologies and determinants for innovation* – *understand the adopter categories for innovation* – *understand the difference between open and closed innovation"* (Prifti, Löffler, et al., 2017a, p. 7).
Curriculum-Specific Content	***"Learning Unit 1.3.1: Digital Innovation Management*** – *Introduction Slides* – *Exercise* – *Case Study* (Prifti, Löffler, et al., 2017a, p. 7)
Software	*"No software required."* (Prifti, Löffler, et al., 2017a, p. 7).
Related Content	
SAP UA	None
External Providers	– openSAP (MOOC): Leadership in Digital Transformation – Coursera (MOOC): Innovation Management – Coursera (MOOC): Design Thinking for Innovation – Coursera (MOOC): Innovation in a Digital World (SAP UCC Munich, 2017o)

5.5.4 Section 2: "Industry 4.0 and Internet of Things"

The second section of the curriculum, "Industry 4.0 and Internet of Things", deals with topics that are characteristic for Industry 4.0 and the IoT and that have impacts on society and workplaces, on social collaboration and project management. It also introduces technical innovations such as the improvements in sensor technology. This section contains four modules.

5.5.4.1 Module 2.1: "Industry 4.0: Society and Workplaces"

Module "2.1 – Industry 4.0: Society and Workplaces" deals with the impacts of these ongoing developments on society and workplaces. The content for this module is presented in Table 42.

Table 42: Module 2.1: "Industry 4.0 and Internet of Things – Society and Workplaces" (with regards to Prifti, Löffler, et al. (2017a))

Section 2: Industry 4.0 and Internet of Things Module 2.1: Society and Workplaces	
Learning Objectives	After working through the module "Society and Workplaces", participants… – *"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"* (Prifti, Löffler, et al., 2017a, p. 8).
Curriculum-Specific Content	***"Learning Unit 2.1.1: Industry 4.0: Society and Workplace[s]*** – *Introduction Slides* (Prifti, Löffler, et al., 2017a, p. 8)
Software	*"No software required."* (Prifti, Löffler, et al., 2017a, p. 8).
Related Content	
SAP UA	None
External Providers	– openSAP (MOOC): Reimagining the Future: A Journey Through the Looking Glass – openSAP (MOOC): The Impact of Digitization on Leadership and Work – openSAP (MOOC): How the Internet of Things and Smart Services Will Change Society (SAP UCC Munich, 2017p)

5.5.4.2 Module 2.2: "Social Collaboration and Project Management"

Module "2.2 – Social Collaboration and Project Management" deals with the impacts of the emerging technologies on two topics that gain more importance in Industry 4.0: (Social) Collaboration and project management. Table 43 presents the content of this module.

Table 43: Module 2.2: "Industry 4.0 and Internet of Things – Social Collaboration and Project Management" (with regards to Prifti, Löffler, et al. (2017a))

Section 2: Industry 4.0 and Internet of Things Module 2.2: Social Collaboration and Project Management	
Learning Objectives	After working through the module "Social Collaboration and Project Management", participants… – *"understand the importance of collaboration in Industry 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"* (Prifti, Löffler, et al., 2017a, p. 8).
Curriculum-Specific Content	***"Learning Unit 2.2.1: Industry 4.0: Social Collaboration and Project Management***

Section 2: Industry 4.0 and Internet of Things Module 2.2: Social Collaboration and Project Management	
	– *Introduction Slides* (Prifti, Löffler, et al., 2017a, p. 8)
Software	*"No software required."* (Prifti, Löffler, et al., 2017a, p. 8).
Related Content	
SAP UA	None
External Providers	None

5.5.4.3 Module 2.3: "Technology Introduction"

Module "2.3 – Technology Introduction" introduces technologies that enable the Digital Transformation and lead to Industry 4.0, e.g., cloud computing. Table 44 presents the content of this module.

Table 44: Module 2.3: "Industry 4.0 and Internet of Things – Technology Introduction" (with regards to Prifti, Löffler, et al. (2017a))

Section 2: Industry 4.0 and Internet of Things Module 2.3: Technology Introduction	
Learning Objectives	After working through the module "Technology Introduction", participants… – *"understand the fundamentals of the [D]igital [T]ransformation* – *understand the megatrends that arise through [the] [D]igital [T]ransformation* – *understand the fundamentals of Industry 4.0* – *understand the fundamentals of the Internet of Things"* (Prifti, Löffler, et al., 2017a, p. 8 f.).
Curriculum-Specific Content	***"Learning Unit 2.3.1: Technology Introduction*** – *Introduction Slides* (Prifti, Löffler, et al., 2017a, p. 9)
Software	*"No software required."* (Prifti, Löffler, et al., 2017a, p. 9).
Related Content	
SAP UA	None
External Providers	– openSAP (MOOC): SAP HANA Could Platform Essentials – openSAP (MOOC): Reimagining the Future: A Journey Through the Looking Glass (SAP UCC Munich, 2017q)

5.5.4.4 Module 2.4: "IoT: Integrating Sensors"

Module "2.4 – IoT: Integrating Sensors" introduces recent developments and new applications of sensors. As sensors generate huge amounts of data, this module has a link to module "7.0 – Smart Data Analytics". Table 45 presents the content of this module.

Table 45: Module 2.4: "Industry 4.0 and Internet of Things – IoT: Integrating Sensors" (with regards to Prifti, Löffler, et al. (2017a))

Section 2: Industry 4.0 and Internet of Things Module 2.4: IoT: Integrating Sensors	
Learning Objectives	After working through the module "IoT: Integrating Sensors", participants… – *"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"* (Prifti, Löffler, et al., 2017a, p. 9).
Curriculum-Specific Content	***"Learning Unit 2.4.1: IoT – Integrating Sensors*** – *Introduction Slides* – *Video* – *Case Study"* (Prifti, Löffler, et al., 2017a, p. 9)
Software	*"SAP HANA"* (Prifti, Löffler, et al., 2017a, p. 9)
Related Content	
SAP UA	None
External Providers	None

5.5.5 Section 3: "Enabling Technologies"

The third section of the curriculum, "Enabling Technologies", deals with the introduction to enabling technologies in general on a more technical level than the second section, and especially with the technologies used in exercises and case studies in this curriculum: SAP HANA and SAP S/4HANA. The introduction of SAP HANA and SAP S/4HANA serves as example for Industry 4.0 applications, but as well as foundation for the practical exercises, e.g., in section 4 – "Integrated Business Processes" or analytic exercises in section 2 – "Industry 4.0 and Internet of Things", as well. This section comprises two learning units.

5.5.5.1 Module 3.1: "Enabling Technologies and Interfaces"

Module "3.1 – Enabling Technologies and Interfaces" gives an overview of software and hardware innovations resulting from the Digital Transformation. The content of this module is listed in Table 46.

Table 46: Module 3.1: "Enabling Technologies – Introduction to Enabling Technologies and Interfaces" (with regards to Prifti, Löffler, et al. (2017a))

Section 3: Enabling Technologies Module 3.1: Introduction to Enabling Technologies and Interfaces	
Learning Objectives	After working through the module "Introduction to Enabling Technologies", participants… – *"[are able to] describe software and hardware innovations*

Section 3: Enabling Technologies **Module 3.1: Introduction to Enabling Technologies and Interfaces**	
	– *understand technologies enabling the [D]igital [T]ransformation and servitization [sic!] of a traditional business* – *understand the integration of the different enabling technologies* – *[are able to] evaluate the resulting business value for companies"* (Prifti, Löffler, et al., 2017a, p. 10).
Curriculum-Specific Content	***"Learning Unit 3.1.1: Introduction to Enabling Technologies and Interfaces*** – *Introduction Slides"* (Prifti, Löffler, et al., 2017a, p. 10)
Software	*"No software required."* (Prifti, Löffler, et al., 2017a, p. 10).
Related Content	
SAP UA	None
External Providers	None

5.5.5.2 Module 3.2: "Introduction to S/4 HANA and Fiori UX"

Module "3.2 – Introduction to S/4HANA and Fiori UX" describes SAP SE's Industry 4.0-ready ERP solution SAP S/4HANA and gives a general overview of the application and the new GUI, Fiori UX. This is important, as this software is the base of some of the exercises and case studies implemented in this curriculum. The modules from section 4, "Integrated Business Processes" build on the knowledge presented in this module (cp. section 5.5.6). The content of this module is listed in Table 47.

Table 47: Module 3.2: "Enabling Technologies – Introduction to S/4HANA and Fiori UX" (with regards to Prifti, Löffler, et al. (2017a))

Section 3: Enabling Technologies **Module 3.2: Introduction to S/4HANA and Fiori UX**	
Learning Objectives	After working through the module "Introduction to S/4HANA and Fiori UX", participants… – *"[are able to] describe SAP S/4HANA and its innovations* – *understand how [SAP] S/4HANA enables the [D]igital [T]ransformation of enterprises* – *understand how SAP Fiori provides a new user experience in […] IS* – *compare the new [SAP] Business Suite S/4HANA to the [SAP] Business Suite powered by [SAP] HANA"* (Prifti, Löffler, et al., 2017a, p. 10).
Curriculum-Specific Content	***"Learning Unit 3.2.1: Introduction to S/4HANA and Fiori UX*** – *Introduction Slides* – *Video* – *Case Study"* (Prifti, Löffler, et al., 2017a, p. 10)
Software	*"SAP S/4 HANA [sic!]* *SAP Fiori 2.0"* (Prifti, Löffler, et al., 2017a, p. 10)
Related Content	
SAP UA	None

Section 3: Enabling Technologies Module 3.2: Introduction to S/4HANA and Fiori UX	
External Providers	– openSAP (MOOC): SAP S/4HANA in a Nutshell – openSAP (MOOC): Find your Path to SAP S/4HANA – openSAP (MOOC): SAP S/4HANA – Deep Dive (SAP UCC Munich, 2017r)

5.5.6 Section 4: "Integrated Business Processes"

Section four of this curriculum, "Integrated Business Processes", shows how the central business processes sales and distribution/CRM, materials management, production planning, finance, controlling, and enterprise asset management are implemented in SAP SE's Industry 4.0-ready ERP system SAP S/4HANA. It is recommended to work through module "3.2 – Introduction to S/4HANA and SAP Fiori UX" from section 3, "Enabling Technologies" before starting with the modules of this section as in that module, the foundations regarding SAP S/4HANA and the corresponding new GUI, SAP Fiori UX, are laid. This section can be seen as successor of the Global Bike curriculum based on SAP ERP, which has been distributed by the SAP UCCs for several years. One idea to illustrate the digital transformation of an ERP system may be to use the old curriculum with its exercises in SAP ERP first, and then switch to section 4 of this new curriculum and compare the look and feel of the SAP ERP system with the SAP S/4HANA system. This section comprises five learning units.

5.5.6.1 Module 4.1: "Sales and Distribution/CRM"

Module "4.1 – Sales and Distribution" introduces the main sales and distribution processes in SAP SE's Industry 4.0-ready ERP solution SAP S/4HANA using the new GUI, Fiori UX. It contains a theoretical introduction as well as hands-on elements such as a case study. This module builds on the knowledge presented in module "3.2 – Introduction to S/4HANA and SAP Fiori UX". The content of this module is listed in Table 48.

Table 48: Module 4.1: "Integrated Business Processes – Sales and Distribution" (with regards to Prifti, Löffler, et al. (2017a))

Section 4: Integrated Business Processes Module 4.1: Sales and Distribution	
Learning Objectives	After working through the module "Sales and Distribution", participants… – *"[are able to] describe all steps of the sales and distribution process of a […] PSS provider* – *understand process innovation and re-design* – *[are able to] explain and analyze [sic!] the impact of digitalization [sic!] 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"* (Prifti, Löffler, et al., 2017a, p. 11).

Section 4: Integrated Business Processes Module 4.1: Sales and Distribution	
Curriculum-Specific Content	***“Learning Unit 4.1.1: Sales and Distribution*** – *Introduction Slides* – *Case Study”* (Prifti, Löffler, et al., 2017a, p. 11)
Software	*“SAP S/4 HANA [sic!], SAP Fiori 2.0”* (Prifti, Löffler, et al., 2017a, p. 11)
Related Content	
SAP UA	– SAP UA: Introduction to SAP ERP Using Global Bike 3.0 (SAP UCC Munich, 2017s)
External Providers	None

5.5.6.2 Module 4.2: “Materials Management”

Module “4.2 – Materials Management” introduces the main materials management and procurement processes in SAP SE’s Industry 4.0-ready ERP solution SAP S/4HANA using the new GUI, Fiori UX. It contains a theoretical introduction as well as hands-on elements such as a case study. This module builds on the knowledge presented in module “3.2 – Introduction to S/4HANA and SAP Fiori UX”. The content of this module is listed in Table 49.

Table 49: Module 4.2: "Integrated Business Processes – Materials Management" (with regards to Prifti, Löffler, et al. (2017a))

Section 4: Integrated Business Processes Module 4.2: Materials Management	
Learning Objectives	After working through the module “Materials Management”, participants… – *“[are able to] describe all steps of materials procurement and management processes* – *understand process innovation and re-design* – *[are able to] explain and analyze [sic!] the impact of digitalization [sic!] 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”* (Prifti, Löffler, et al., 2017a, p. 11).
Curriculum-Specific Content	***“Learning Unit 4.2.1: Materials Management*** – *Introduction Slides* – *Case Study”* (Prifti, Löffler, et al., 2017a, p. 11)
Software	*“SAP S/4 HANA [sic!], SAP Fiori 2.0”* (Prifti, Löffler, et al., 2017a, p. 11)
Related Content	
SAP UA	– SAP UA: Introduction to SAP ERP Using Global Bike 3.0 (SAP UCC Munich, 2017t)
External Providers	None

5.5.6.3 Module 4.3: “Finance and Controlling”

Module “4.3 – Finance and Accounting” introduces the main financial accounting and controlling processes in SAP SE’s Industry 4.0-ready ERP solution SAP S/4HANA using the new GUI, Fiori UX. It contains a theoretical introduction as well as hands-on elements such as a case study. This module builds on the knowledge presented in module “3.2 – Introduction to S/4HANA and SAP Fiori UX”. The content of this module is listed in Table 50.

Table 50: Module 4.3: "Integrated Business Processes – Finance and Controlling" (with regards to Prifti, Löffler, et al. (2017a))

Section 4: Integrated Business Processes Module 4.3: Finance and Controlling	
Learning Objectives	After working through the module “Finance and Controlling”, participants… – *“[are able to] describe [f]inance and [c]ontrolling of a […] [.]PSS[.] provider* – *understand process innovation and re-design* – *[are able to] explain and analyse [sic!] the impact of digitalization [sic!] on these processes* – *understand how the products and processes of GBI are transforming* – *understand the integration of [f]inance and [c]ontrolling with further processes in the company”* (Prifti, Löffler, et al., 2017a, p. 11).
Curriculum-Specific Content	***“Learning Unit 4.3.1: Finance and Controlling*** – *Introduction Slides* – *Case Study”* (Prifti, Löffler, et al., 2017a, p. 12)
Software	*“SAP S/4 HANA [sic!], SAP Fiori 2.0”* (Prifti, Löffler, et al., 2017a, p. 12)
Related Content	
SAP UA	– SAP UA: Introduction to SAP ERP Using Global Bike 3.0 (SAP UCC Munich, 2017u)
External Providers	None

5.5.6.4 Module 4.4: “Enterprise Asset Management”

Module “4.4 – Enterprise Asset Management” introduces the main enterprise asset management and maintenance processes in SAP SE’s Industry 4.0-ready ERP solution SAP S/4HANA using the new GUI, Fiori UX. It contains a theoretical introduction as well as hands-on elements such as a case study. This module builds on the knowledge presented in module “3.2 – Introduction to S/4HANA and SAP Fiori UX”. The content of this module is listed in Table 51.

Table 51: Module 4.4: "Integrated Business Processes – Enterprise Asset Management" (with regards to Prifti, Löffler, et al. (2017a))

Section 4: Integrated Business Processes Module 4.4: Enterprise Asset Management	
Learning Objectives	After working through the module “Enterprise Asset Management”, participants… – *“[are able to] describe the […] [EAM] of a […] [.]PSS[.] provider* – *understand process innovation and re-design*

Section 4: Integrated Business Processes **Module 4.4: Enterprise Asset Management**	
	– *[are able to] explain and analyse [sic!] the impact of digitalization [sic!] on these processes* – *understand how the products and processes of GBI are transforming* – *understand the integration of EAM with further processes in the company"* (Prifti, Löffler, et al., 2017a, p. 12).
Curriculum-Specific Content	***"Learning Unit 4.4.1: Enterprise Asset Management*** – *Introduction Slides* – *Case Study"* (Prifti, Löffler, et al., 2017a, p. 12)
Software	*"SAP S/4 HANA [sic!], SAP Fiori 2.0"* (Prifti, Löffler, et al., 2017a, p. 12)
Related Content	
SAP UA	– SAP UA: Introduction to SAP ERP Using Global Bike 3.0 (SAP UCC Munich, 2017v)
External Providers	None

5.5.6.5 Module 4.5: "Production Planning"

Module "4.5 – Production Planning" introduces the main production, planning, and production planning processes in SAP SE's Industry 4.0-ready ERP solution SAP S/4HANA using the new GUI, Fiori UX. It contains a theoretical introduction as well as hands-on elements such as a case study. This module builds on the knowledge presented in module "3.2 – Introduction to S/4HANA and SAP Fiori UX". The content of this module is listed in Table 52.

Table 52: Module 4.5: "Integrated Business Processes – Production Planning" (with regards to Prifti, Löffler, et al. (2017a))

Section 4: Integrated Business Processes **Module 4.5: Production Planning**	
Learning Objectives	After working through the module "Production Planning", participants… – *"understand and [are able to] describe the production planning process of a […] PSS provider* – *[are able to] explain and analyze [sic!] the impact of digitalization [sic!] on these processes* – *[are able to] analyze [sic!] and evaluate [m]ake or [b]uy decisions* – *understand the integration of production planning with further processes in the company"* (Prifti, Löffler, et al., 2017a, p. 12).
Curriculum-Specific Content	***"Learning Unit 4.5.1: Production Planning*** – *Introduction Slides* – *Case Study"* (Prifti, Löffler, et al., 2017a, p. 12)
Software	*"SAP S/4 HANA [sic!], SAP GUI 7.5"* (Prifti, Löffler, et al., 2017a, p. 12)
Related Content	
SAP UA	– SAP UA: Introduction to SAP ERP Using Global Bike 3.0 (SAP UCC Munich, 2017w)

Section 4: Integrated Business Processes Module 4.5: Production Planning	
External Providers	None

5.5.7 Sections 5 – 9: "Cross-Cutting Topics"

There are topics that touch some of the previous mentioned topics, e.g., digital security or big data analytics play a role in business models and strategy, but are connected to technologies and the IoT as well. The topics are subsumed as "Cross-Cutting Topics". However, they all do have specific characteristics but are only loosely connected to one another. Therefore, in a way they represent own sections – and get their own section number each. This section contains five modules.

5.5.7.1 Module 5.0: "Digital Security"

Section or Module "5.0 – Digital Security" gives an overview of security issues that emerge with the Digital Transformation and Industry 4.0. Table 53 presents the content of this module.

Table 53: Module 5.0: "Digital Security" (with regards to Prifti, Löffler, et al. (2017a))

Section 5: Digital Security Module 5.0: Digital Security	
Learning Objectives	After working through the module "Digital Security", participants… – *"understand the main security threats in an Industry 4.0 environment* – *are able to recognize [sic!] security threats in a connected environment"* (Prifti, Löffler, et al., 2017a, p. 13).
Curriculum-Specific Content	***"Learning Unit […] [5.0[67]]: Digital Security*** – *Introduction Slides"* (Prifti, Löffler, et al., 2017a, p. 13)
Software	*"No software required."* (Prifti, Löffler, et al., 2017a, p. 13).
Related Content	
SAP UA	None
External Providers	– openSAP (MOOC): Cybersecurity – The Essential Challenge for Digital Transformation – Coursera (MOOC): Cybersecurity and the Internet of Things (SAP UCC Munich, 2017x)

[67] Numeration of the modules and learning units is different in the curriculum "The Digital Transformation of Global Bike" (SAP UCC Munich: Project Curriculum Development, 2016 - 2017) and in the description presented in the Lecturer Notes by Prifti, Löffler, et al. (2017a). In this work, we stick to the numeration of the curriculum.

5.5.7.2 Module 6.0: "Social Media"

Section or Module "6.0 – Social Media" introduces social media topics, including the blurring of private and publicly available personal data and possible impacts on the professional live of an individual. Table 54 presents the content of this module.

Table 54: Module 6.0: "Social Media" (with regards to Prifti, Löffler, et al. (2017a))

Section 6: Social Media Module 6.0: Social Media	
Learning Objectives	After working through the module "Social Media", participants… – *"understand how social media can add business value* – *understand how their private behavior [sic!] in social media might affect their professional lives"* (Prifti, Löffler, et al., 2017a, p. 13).
Curriculum-Specific Content	***"Learning Unit […] [6.0[68]]: Social Media*** – *Introduction Slides* – *Case Study"* (Prifti, Löffler, et al., 2017a, p. 13)
Software	*"No software required."* (Prifti, Löffler, et al., 2017a, p. 13).
Related Content	
SAP UA	None
External Providers	None

5.5.7.3 Module 7.0: "Smart Data Analytics"

For reasons of demonstration, this module was already explained in detail in section 5.5.1.

5.5.7.4 Module 8.0: "SMAC (Social, Mobile, Analytics, Cloud)"

Section or Module "8.0 – SMAC (Social, Mobile, Analytics, Cloud)" gives an overview of the four topics social media, mobile devices/availability, smart data analytics, and cloud computing, that are part of Digital Transformation and Industry 4.0. Table 54 presents the content of this module.

Table 55: Module 8.0: "SMAC (Social, Mobile, Analytics, Cloud)" (with regards to Prifti, Löffler, et al. (2017a))

Section 8: SMAC (Social, Mobile, Analytics, Cloud) Module 8.0: SMAC (Social, Mobile, Analytics, Cloud)	
Learning Objectives	After working through the module "Smart Data Analytics", participants… – *"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"*

[68] Numeration of the modules and learning units is different in the curriculum "The Digital Transformation of Global Bike" (SAP UCC Munich: Project Curriculum Development, 2016 - 2017) and in the description presented in the Lecturer Notes by Prifti, Löffler, et al. (2017a). In this work, we stick to the numeration of the curriculum.

Section 8: SMAC (Social, Mobile, Analytics, Cloud) Module 8.0: SMAC (Social, Mobile, Analytics, Cloud)	
	– *understand the main aspects of the component "Analytics"* – *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"* (Prifti, Löffler, et al., 2017a, p. 14).
Curriculum-Specific Content	***"Learning Unit 8.0.1[69]: SMAC*** – *Introduction Slides"* (Prifti, Löffler, et al., 2017a, p. 14)
Software	*"No software required."* (Prifti, Löffler, et al., 2017a, p. 14).
Related Content	
SAP UA	None
External Providers	None

5.5.7.5 Module 9.0: "Cross-Cutting Topics – Design Thinking"

In the curriculum development project, we applied the Design Thinking approach, as we are convinced that it can support work on interdisciplinary topics because one of its strengths is to bring people with different backgrounds together for working on one project. Working in interdisciplinary teams becomes more important with Industry 4.0. Therefore, we decided to add a module for imparting the concepts and the use of the Design Thinking approach. We conducted Design Thinking workshops in two classes with 20, respective 18 IS master students in summer term 2017 and winter term 2017/18 at TUM in Garching bei München, Germany. We integrated these workshops in student development projects with the topic of smart data analytics. Compared to previously conducted classes, this led to better project organization in the student projects and added value to the student development projects, e.g., in case of the problem definition and generation of solution proposals. The feedback of the students was very positive – on the one hand regarding the workshop, on the other hand as they rated the methods learned in the workshop very helpful for their project work in the class as well as for future project work in other classes or in their jobs. They emphasized that it improved their communication and the gaining of a common understanding of the project task and definition. Moreover, during and after the workshops, they came up with completely new solution approaches than before.

Therefore, we added our materials and experiences as module "9.0 Design Thinking" in the column of Cross-Cutting Topics (cp. Table 56). It contains workshop materials for conducting a Design Thinking workshop as well as links on MOOCs from different areas that show how Design Thinking can be applied in different fields.

[69] Numeration of the modules and learning units is different in the curriculum "The Digital Transformation of Global Bike" (SAP UCC Munich: Project Curriculum Development, 2016 - 2017) and in the description presented in the Lecturer Notes by Prifti, Löffler, et al. (2017a). In this work, we stick to the numeration of the curriculum.

Table 56: Module 9.0: "Design Thinking" (with regards to Prifti, Löffler, et al. (2017a))

Section 9: Design Thinking Module 9.0: Smart Data Analytics	
Learning Objectives	After working through the module "Smart Data Analytics", participants… – *"understand and [are able to] apply [D]esign [T]hinking for discussion and idea generation* – *[are able to] work in teams and present the results of the work"* (Prifti, Löffler, et al., 2017a, p. 15).
Curriculum-Specific Content	***"Learning Unit 9.0.1: Design Thinking*** – *Slide Deck for conducting a Design Thinking workshop* – *Example Challenges"* (Prifti, Löffler, et al., 2017a).
Software	*"No software required."* (Prifti, Löffler, et al., 2017a, p. 15).
Related Content	
SAP UA	None
External Providers	– openSAP (MOOC): Developing Software Using Design Thinking – openSAP (MOOC): SAP SE's UX Strategy in a Nutshell by Sam Yen – Coursera (MOOC): Design for Innovation (SAP UCC Munich, 2017ab)

5.6 Learning Journeys

The architecture of the Industry 4.0 curriculum "The Digital Transformation of Global Bike" comprises the presentation of content in modules. This allows lecturers to individually choose and combine modules from one or different sections for their specific lecture. However, lecturers are different in tailoring their lectures. In the focus group interviews as well as during evaluation, we got the feedback, that some lecturers welcome the idea of being able to tailor their own lecture using the bricks offered by a modular-based curriculum. They appreciate to choose between introduction lectures and deep dives. Others lecturers expressed difficulties in handling this new degree of freedom – they would prefer to have a specific amount of materials arranged in a specific order to directly use in their classes.

To address both needs, several education or training providers offer "Learning Journeys". The project development team concluded that the implementation of guided learning journeys for specific topics would add value to the curriculum. A learning journey in this case is a "guided tour" through the curriculum, which contains materials relevant for a specific topic collected from different modules and provides a deep dive enhanced with external materials.

With regards to the results from the literature review (cp. section 4.1.1), the focus group interviews (cp. section 4.1.2), and the competency model for employees in Industry 4.0 (cp. section 4.3), we identified eight topics for implementing learning journeys for the first release of the Industry 4.0 curriculum "The Digital Transformation of Global Bike". The learning journeys are independent from one another. A lecturer can choose a topic and then start right away with the corresponding learning journey.

- **“Business Model and Strategy”**: Deep dive into strategic topics – going far beyond the contents of the section “Business Model and Strategy”, enhanced with external materials
- **“Industrie 4.0 and IoT”**: Deep dive into typical Industry 4.0 aspects, enhanced with external materials
- **“Enabling Technologies”**: Deep dive into technological topics, enhanced with external materials
- **“Sentiment Analysis”**: Special application of analytics with focus on practical experience
- **“Integrated Business Processes”**: Enhancement of the section “Integrated Business Processes”, including a deep dive with external materials
- **“Cross-Cutting Topics”**: Deep dive into “Cross-Cutting Topics”, enhanced with external materials
- **“Digital Innovation”**: Focus on innovation topics, enhanced with external materials
- “**IoT and Data Analytics”**: Focus on analytics based on IoT-technology

On first sight, some of the titles of the learning journeys sound quite similar to some of the curriculum modules. However, the learning journeys go beyond the content of the modules and integrate content from several modules. Moreover, learning journeys comprise links to external content such as MOOCs as well in the same way as the curriculum modules do (cp. section 5.5.1). Furthermore, the content of the learning journeys is divided into the categories “Introduction”, “Deep Dive”, and “Special Topics”. “Introduction” comprises the entry to a topic; usually no previous knowledge is required. The content from the category “Deep Dive” builds on previous knowledge and targets on providing a deeper knowledge and a broader understanding. The category “Special Topics” contains no general materials, but deep dives into specific topics related to the overall topic of the learning journey. These “Special Topics” are not contained in the modules but only in the learning journeys. Previous knowledge of the topic is needed in this section.

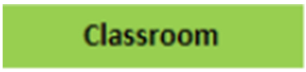
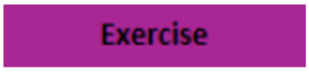
There is no standard for how much time a lecturer can spend on a topic, as we want to address lecturers of different subjects in different institutions of higher education and in different countries. Therefore, each learning journey focusses on a specific topic and contains related content. As the topics are of different complexity, some learning journeys contain more content than others. Lecturers can decide if they choose to use a whole learning journey, or skip, e.g., the deep dive-topics. Of course, they still have to adjust the content to the length of their classes.

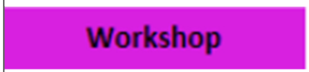
On the landing page for the learning journeys in the curriculum navigation application, all learning journeys are listed, including title, a short description, and the specific target audience (SAP UCC Munich, 2017l). There is no description of software requirements or similar. This is because the learning journeys are more comprehensive than the curriculum modules. If someone is interested in a topic, he may navigate to the learning journey – and then choose which of the elements presented in the learning journey he wants to use. Each element has its own description of its content, target audience, and software requirements.

5.6.1 Overview of Learning Journeys

In the following sections, the learning journeys of the first release of the Industry 4.0 curriculum "The Digital Transformation of Global Bike" are presented. For each learning journey, there is a table with a description of the goal and the content of the learning journey and the target audience. Each table is followed by a graphical representation of the learning journey, which illustrates the content and elements of the learning journey. In the top right corner, the modules and corresponding sections of the curriculum are displayed, which are referred to in the learning journey. The icons introduced in Table 57 indicate, which kind of content or activity is comprised in the different elements of the learning journeys.

Table 57: Icons Used in Learning Journeys

Icon	Meaning
 **Figure 37: LearningJourneys: Icon "Case Study"***	The icon "Case Study" (red) refers to a case study. Students have to get active to fulfil comprehensive tasks to deepen their knowledge. This may comprise the use of software applications such as SAP HANA or SAP S/4HANA. Case studies may be provided for single students or small groups. They may take more time than available in one single lecture.
 **Figure 38: Learning Journeys: Icon "Classroom"***	The icon "Classroom" (green) refers to materials for classroom lectures – for the introduction of a topic as well as for deep dives on specific topics. In most cases, slide decks are available for classroom lectures.
 **Figure 39: Learning Journeys: Icon "Exercise"***	The icon "Exercise" (purple) refers to an exercise. Students have to get active to fulfil a small, limited task to deepen their knowledge. This may comprise the use of software applications such as SAP HANA or SAP S/4HANA. Exercises may be provided for single students or small groups. They usually can be conducted within the scope of a single lecture.
 **Figure 40: Learning Journeys: Icon "Hands-on"****	The icon "Hands-on" (yellow) refers to one or more exercises, a case studie, or the like. Students have to get active to fulfil tasks to deepen their knowledge. This may comprise the use of software applications such as SAP HANA or SAP S/4HANA. It may as well contain exercises for single students or small groups.
 **Figure 41: Learning Journeys: Icon "MOOC"***	The icon "MOOC" (blue) refers to a MOOC, provided by an external provider such as openSAP, coursera, Alison, or Class Central. While collecting content for the curriculum "The Digital Transformation of Global Bike", our goal was to choose MOOCs which are freely and long-term available. However, external content may be subject to changes. The MOOCs support the topics of the learning journeys by offering deep insights to special aspects of the topics – or by going more into detail than the foundation materials provided in the scope of the curriculum.

Icon	Meaning
 **Figure 42: Learning Journeys: Icon "Video"***	The icon “Video” (brown) refers to a link to a video that deals with the chosen context. The video may be provided in the scope of the curriculum “The Digital Transformation of Global Bike” or by an external provider or platform, e.g., YouTube[70].
 **Figure 43: Learning Journeys: Icon "Workshop"*****	The icon “Workshop” (pink) refers to materials that are suited to conduct a workshop with a group of people. A workshop has to be well prepared by the lecturer. Maybe, additional materials and a special location have to be organized in advance. A workshop usually takes more time than one usual lecture. Thus, it might be a good idea to plan an extra appointment.
* Screenshots from curriculum “The Digital Transformation of Global Bike” (SAP UCC Munich, 2017f). ** Screenshot from curriculum “The Digital Transformation of Global Bike” (SAP UCC Munich, 2017i). *** Screenshot from curriculum “The Digital Transformation of Global Bike” (SAP UCC Munich, 2017k). **** Screenshot from curriculum “The Digital Transformation of Global Bike” (SAP UCC Munich, 2017g).	

5.6.1.1 Learning Journey “Business Model and Strategy”

As Industry 4.0 will significantly affect business models and business strategies, we implemented a learning journey “Business Model and Strategy”. Compared with curriculum section 1 – “Business Models and Strategy”, it offers a further deep dive into this topic, including external content. Table 58 contains the content, advices of how to use the learning journey, and the target audience of this learning journey.

Table 58: Learning Journey "Business Model and Strategy"

Learning Journey “Business Model and Strategy”	
Description	*“This learning journey provides a closer look at business models and business strategy. After starting with an introduction to the main concepts of [s]trategy and [b]usiness [m]odels, the students can conduct exercises and teamwork in order to deepen their knowledge. For a deep dive[,] we suggest the module [“]Business Change Management[”] as well as the MOOCs [“]Business Strategy[”] and [“]Digital Business Models[”]. For interested publicum [sic! “audience”, the author] [,] we suggest the MOOC [“]Business Strategies for Emerging Markets[”] as a special topic of interest.”* (SAP UCC Munich, 2017l).
Target Audience	*“[S]tudents of Information Systems and Economics following their studies in [b]achelor or [m]aster degree interested in the influence of the [D]igital [T]ransformation on business models and company strategy”* (SAP UCC Munich, 2017l).

[70] YouTube: Video-providing portal of YouTube, LLC (part of Google, LLC). https://www.youtube.com/. Accessed on May 22nd, 2018.

As introduction of this learning, we recommend the curriculum module “Strategy & Business Model Innovation”. As deep dive, we recommend the curriculum module “Business Change Management”, which deals with the transition from an existing business model to a new one. Furthermore, two MOOCs (external content) are listed for getting deeper into the topic: “Business Strategy” and “Digital Business Models” which deal with business models that develop in the scope of Industry 4.0 in general. As special topic with a special focus, the learning journey contains the MOOC “Business Strategies for Emerging Markets” (external content). This focusses not on “traditional industries” but on new markets that emerge with Industry 4.0. General knowledge about business models and business strategy – as provided in the introduction and deepened in the deep dive – is needed to understand the specifics of this special topic. Figure 44 gives an overview of the content that is available in the categories “Introduction”, “Deep Dive”, and “Special Topics” for this learning journey.

Figure 44: Learning Journey "Business Model and Strategy" (screenshot from curriculum "The Digital Transformation of Global Bike", provided by SAP UCC Munich (2017f))

5.6.1.2 Learning Journey "Industrie 4.0 and IoT"

The topic of the curriculum at hand is Industry 4.0. The learning journey "Industrie 4.0 and IoT" offers an introduction and, in addition to curriculum section 2 – "Industry 4.0 and Internet of Things", a deep dive into the characteristic aspects of Industry 4.0, including external content. Table 59 contains the content and advices of how to use the learning journey, as well as the target audience of this learning journey.

Table 59: Learning Journey "Industrie 4.0 and IoT"

Learning Journey “Industrie 4.0 and IoT”	
Description	*“This learning journey provides a closer look at the topics Industrie 4.0 and the Internet of Things. We suggest in [sic!] starting an introduction with the [m]odule [“]Society and Workplace[”] that includes a theory slide deck. For a deep dive[,] we suggest the modules [“]Social Collaboration and Project Management[”] and [“]Technology Introduction[”], which also both include theory slides. After this introduction[,] the [sic!] students can earn some hand[s]-on experience with the module [“]IoT: Integrating Sensors[”,] that includes hands-on exercises on the HANA system, also by including the data generation with a Rasberry [sic!] Pi and the analyzis [sic!] of the generated data. To further deepen their knowledge[,] the students can follow the MOOCs [“]Imagine IoT[”] as well as [“]How IoT & Smart Services Will Change Society[”]. As a special topic you may consider the MOOC [“]Cybersecurity and the Internet of Things[”].”* (SAP UCC Munich, 2017l).
Target Audience	*“[S]tudents of Information Systems, Informatics[,] and Engineering in their [b]achelor or [m]aster studies, who are interested in topics of [sic!] IoT and Industry 4.0 as well as the role of sensors in these technologies”* (SAP UCC Munich, 2017l)

This learning journey starts with a general overview of how Industry 4.0 affects the society and workplaces in the curriculum module “Society and Workplace”. Main aspects of Industry 4.0 are collaboration on the one hand and technological developments such as IoT, sensors, etc. on the other hand. Therefore, in the deep dive, we added the curriculum module “Social Collaboration/Project Management” and the MOOCs “Imagine IoT” (external content) and “How IoT & Smart Services Will Change Society” (external content) for exploring collaboration and society topics. The curriculum modules “Technology Introduction” and “IoT, Integrated Sensors” offer a deeper introduction to technical aspects of Industry 4.0. As special topic, we added the MOOC “Cybersecurity and the Internet of Things” (external content) as from our opinion it is crucial to generate awareness for security threats that emerge in a highly connected environment. Figure 45 gives an overview of the content, which is available in the categories “Introduction”, “Deep Dive”, and “Special Topics” for this learning journey.

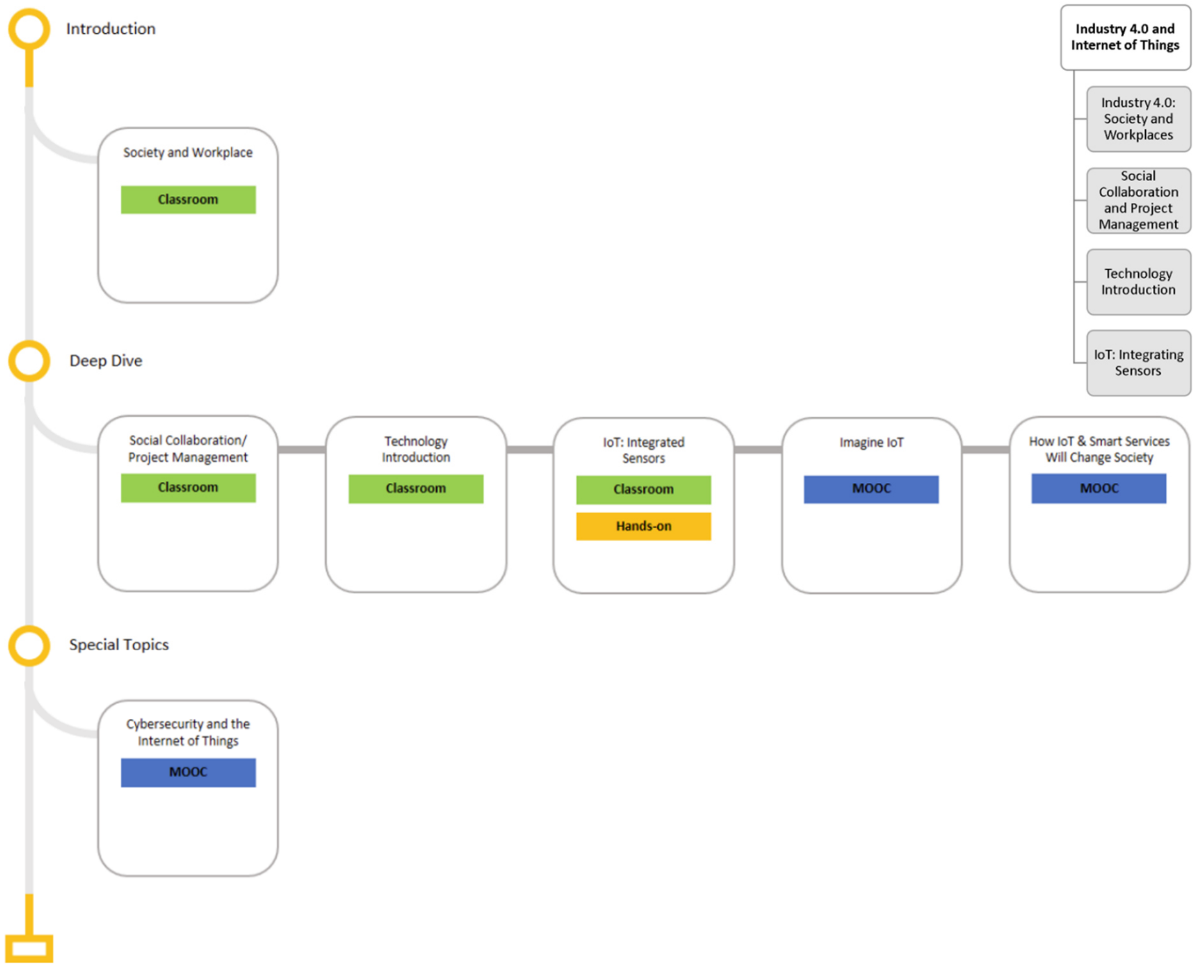


Figure 45: Learning Journey "Industrie 4.0 and IoT" (screenshot from curriculum "The Digital Transformation of Global Bike", provided by SAP UCC Munich (2017i))

5.6.1.3 Learning Journey "Enabling Technologies"

Industry 4.0 comes with technological changes. This is true for ERP systems as well. Therefore, the learning journey "Enabling Technologies" offers a deep dive into this topic, including information about new technologies in general, but as well an overview of SAP's Industry 4.0-ready ERP system, SAP S/4HANA. It goes beyond the content of curriculum section 3 – "Enabling Technologies" and includes external content. Table 60 contains the content and advices of how to use the learning journey, as well as the target audience of this learning journey.

Table 60: Learning Journey "Enabling Technologies"

Learning Journey “Enabling Technologies”	
Description	*“This learning journey provides a closer look at the enabling technologies of Industrie 4.0 and the Internet of Things and gives a concrete introduction in the new SAP ERP [s]ystem S/4 HANA [sic!]. It starts with an introduction in [sic!] the [“]Enabling Technologies and Interfaces[”] followed by the module [“]Introduction to S/4 HANA and Fiori UX[”] [sic!]. Both modules include theory slides as well as hands-on exercises by giving the possibility to test out the new functionalities of S/4 HANA [sic!]. For a further deep dive[,] we suggest the MOOCs [“]SAP S/4 HANA Deep Dive[”] [sic!] as well as [“]SAP S/4 HANA Use Cases[”] [sic!]. For students with deep interest on [sic!] the topic[,] we also suggest the special topic [“]SAP Fiori for iOS[71”,] which is offered as a MOOC by openSAP.”* (SAP UCC Munich, 2017l).
Target Audience	*“[S]tudents of various disciplines and study degrees icluding [sic!] [b]achelor and [m]aster students of Information Systems, Informatics, Engineering[,] and Economics, who are interested in the latest technology development[s] in the area of ERP [s]ystems”* (SAP UCC Munich, 2017l)

We recommend starting this learning journey with a general introduction to enabling technologies, using the curriculum module “Emerging Technologies and Interfaces”. In the deep dive, this learning journey focusses on a general overview of SAP’s new ERP system, SAP S/4HANA, using the curriculum module “Introduction to S/4HANA and Fiori UX” and the MOOCs “SAP S/4HANA Deep Dive” (external content) and “SAP S/4HANA Use Cases” (external content). As special topic, this learning journey offers an introduction to the integration of the new GUI of SAP S/4HANA – Fiori – with iOS, as mobile devices play a major role in Industry 4.0. Therefore, it recommends the MOOC “SAP Fiori for iOS” (external content). Figure 46 gives an overview of the content, which is available in the categories “Introduction”, “Deep Dive”, and “Special Topics” for this learning journey.

[71] iOS: iPhone OS; mobile operating system developed by Apple Inc.

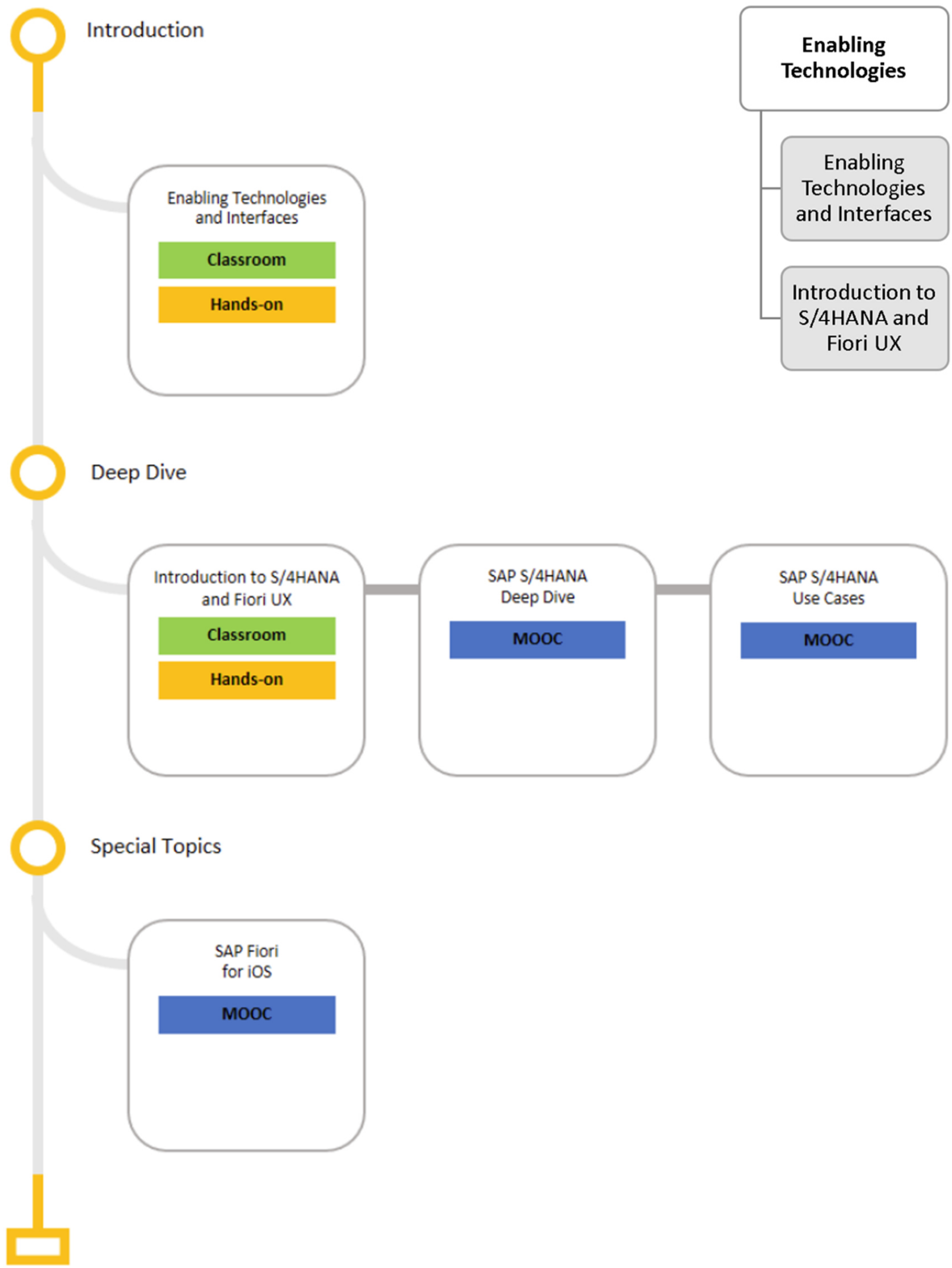


Figure 46: Learning Journey "Enabling Technologies" (screenshot from curriculum "The Digital Transformation of Global Bike", provided by SAP UCC Munich (2017h))

5.6.1.4 Learning Journey "Sentiment Analysis"

Sentiment analysis is a popular example for the analysis of unstructured big data, one of the topics, that gains more importance with Industry 4.0. Therefore, the learning journey "Sentiment Analysis" offers a small, practical deep dive into this topic. Table 61 contains the content and advices of how to use the learning journey, as well as the target audience of this learning journey.

Table 61: Learning Journey "Sentiment Analysis"

Learning Journey "Sentiment Analysis"	
Description	*"This learning journey provides a closer look at [s]entiment [a]nalysis, e.g., on customer reviews. It provides an introduction through the SAP UA [c]ourse[.] ["]Introduction to SAP HANA Curriculum["]. After learning the basics about HANA and existing algorithms, the students can deep dive into the topic with the module ["]Introduction to Sentiment Analysis[",] which includes theory slides as well as videos and hands-on exercises on the SAP HANA[-]system. In […] [this] module[,] students learn to analyse customer feedback and try to make sens [sic!] of the customer reviews and extract business value from it."* (SAP UCC Munich, 2017l).
Target Audience	*"[S]tudents of Information Systems and Informatics studying in [b]achelor or [m]aster degree that are interested in topics of analytics and in-memory databases"* (SAP UCC Munich, 2017l)

As the practical exercise is based on SAP HANA, the introduction starts with becoming familiar with this in-memory database using the module "SAP UA: Introduction to SAP HANA Curriculum" (external content). Building on this, the deep dive contains the curriculum module "Introduction to Sentiment Analysis" which goes deeper into the topic with a video and more detailed hands-on exercises. Figure 47 gives an overview of the content, which is available in the categories "Introduction" and "Deep Dive" for this learning journey.

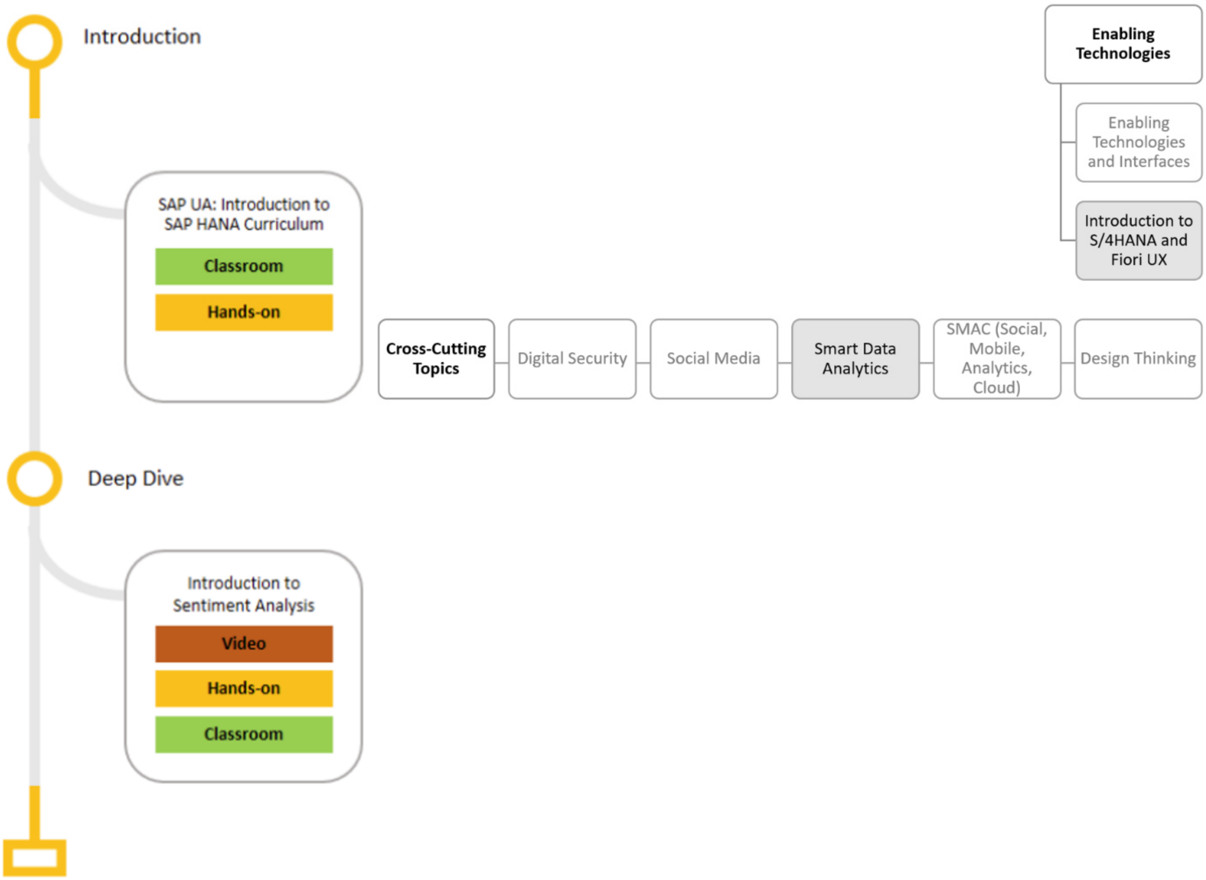


Figure 47: Learning Journey "Sentiment Analysis" (screenshot from curriculum "The Digital Transformation of Global Bike", provided by SAP UCC Munich (2017k))

5.6.1.5 Learning Journey "Integrated Business Processes"

With Industry 4.0, business processes will change as well. The learning journey "Integrated Business Processes" offers a deep dive into this topic at the example of the business processes in SAP S/4HANA, focussing on practical exercises. In comparison to curriculum section 4 – "Integrated Business Processes", it goes beyond and includes special topics and external content. Table 62 contains the content and advices of how to use the learning journey, as well as the target audience of this learning journey.

Table 62: Learning Journey "Integrated Business Processes"

Learning Journey “Integrated Business Processes”	
Description	*“This learning journey provides a closer look at integrated business processes[,] which offer the core activities of every enterprise. The learning path start [sic!] with an introduction to S/4 HANA [sic!] and Fiori UX. After learning the basics, the students can deep dive to the single modules including [“S]ales and [D]istribution[”], [“M]aterials [M]anagement[”], [“F]inance and [C]ontrolling[”], [“E]nterprise [A]sset [M]anagement[”,] and [“P]roduction [P]lanning[”]. For each of this [sic!] modules[,] a basic theoretical introduction to the process is provided as well as hands-on exercises on the S/4 HANA [sic!] system. For students[,] who have a special interest in the topic[,] we also suggest the special topics MOOCs[.] [“]Process Improvement[”], [“]Advanced Manufacturing Process Analysis[”], [and “]Digital Transformation Across the Extended Supply Chain[”].”* (SAP UCC Munich, 2017l).
Target Audience	*“[S]tudents of Information Systems and Economics in their [b]achelor or [m]aster studies who are interested in topic [sic!] of process management, process integration[,] and transformation”* (SAP UCC Munich, 2017l)

As introduction, the learning journey starts with the curriculum module “Introduction to S/4HANA and Fiori UX”. Building on this, it contains the practical introduction to business processes in SAP S/4HANA as deep dive, using the corresponding curriculum modules “Sales and Distribution”, “Materials Management”, “Finance and Controlling”, “Enterprise Asset Management”, and “Production Planning”. Who wants to go further can choose one or more of the special topics, presented in the MOOCs “Process Improvement” (external content), Advanced Manufacturing Process Analysis” (external content), and “Digital Transformation Across the Extended Supply Chain” (external content). Figure 48 gives an overview of the content, which is available in the categories “Introduction”, “Deep Dive”, and “Special Topics” for this learning journey.

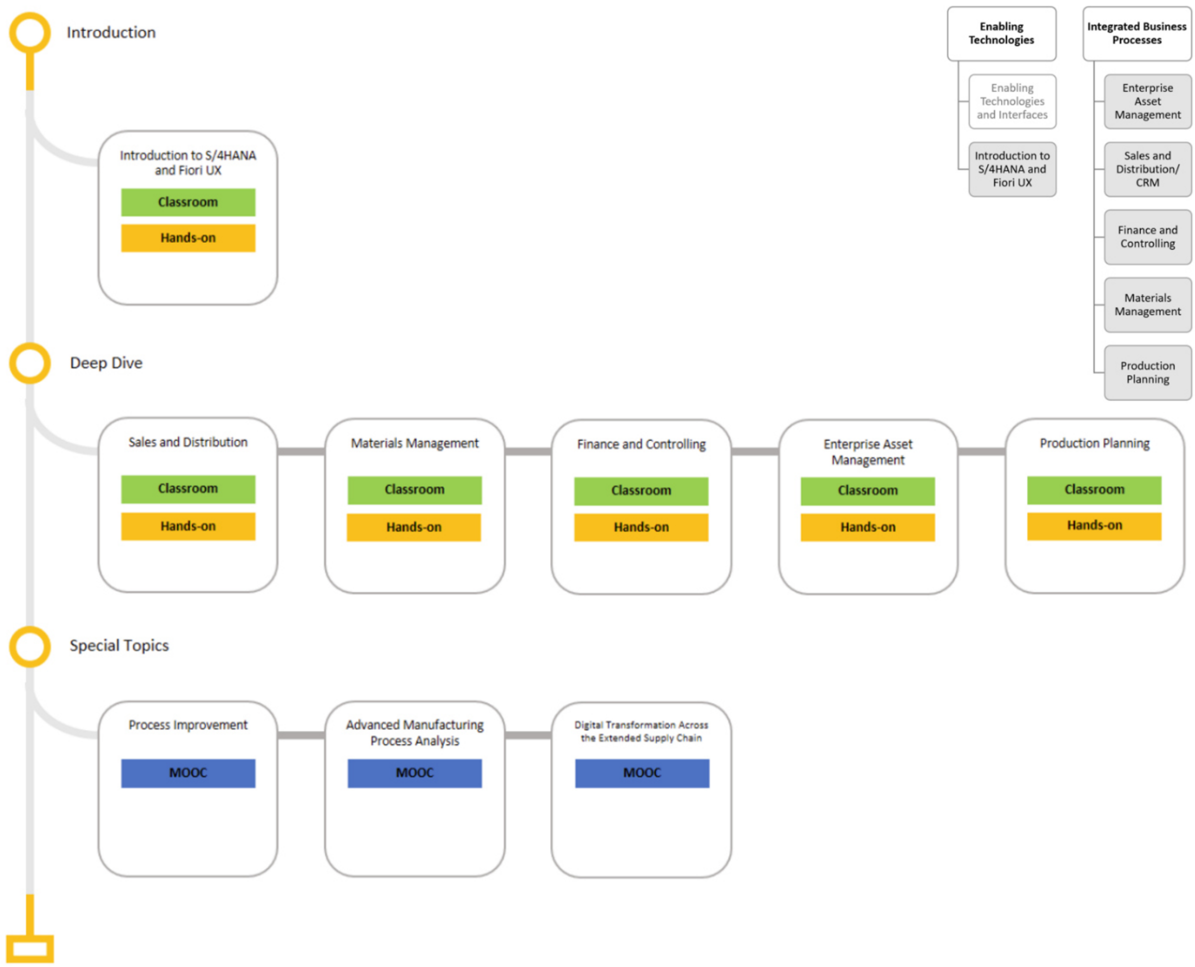


Figure 48: Learning Journey "Integrated Business Processes" (screenshot from curriculum “The Digital Transformation of Global Bike”, provided by SAP UCC Munich (2017b))

5.6.1.6 Learning Journey “Cross-Cutting Topics”

When defining the curriculum modules and sections, we already added a section for crosscutting topics that affect several of the other sections. E.g., SMAC influences business models and strategies; digital security is connected with technology, etc. The learning journey “Cross-Cutting Topics” offers a deep dive into crosscutting topics, and goes beyond the content of curriculum sections 5 – 9 – “Cross-Cutting Topics”, by adding external content. Table 63 contains the content and advices of how to use the learning journey, as well as the target audience of this learning journey.

Table 63: Learning Journey "Cross-Cutting Topics"

Learning Journey “Cross-Cutting Topics”	
Description	*“The learning journey provides a closer look at cross-cutting topics in the scope of Industrie 4.0. Industrie 4.0 influences many aspects. Some of the main trends that are part of Industrie 4.0 are considert [sic!] [as “]SMAC[”]. Smac stand [sic!] for Social[,] Mobile, Analytics[,] and Cloud”. The learning journey starts with a brief introduction to the four trends. For a deep dive[,] we suggest the modules [“]Social Media[”] and [“]Big Data Analytics and Data Mining[”], which offer a deeper understanding of the trends based also on exercises as role play[s] and hands-on case studies. Further suggested content are the MOOCs [“]Driving Business Results with Big Data[”] as well as [“]Emerging Technologies in Wireless Communication[”]. For students with a high interest on [sic!] on the topic[,] we also suggest the special topic MOOC [“]Cybersecurity and the Internet of Things[”].”* (SAP UCC Munich, 2017l).
Target Audience	*“[S]tudents of Information Systems, Informatics and Economics in their [b]achelor or [m]aster studies, who are interested in the special topics and trends affecting Industrie 4.0”* (SAP UCC Munich, 2017l)

We recommend to start this learning journey with the curriculum module “S-M-A-C (Social, Mobile, Analytics, Cloud)” in order to build the knowledge foundation that is needed for the further topics. As deep dive, we propose to choose from the curriculum modules “Social Media”, Big Data Analytics and Data Mining”, and “Digital Security”, or from the MOOCs (external content) “Driving Business Results with Big Data” and “Emerging Technologies in Wireless Communication”. As special topic, we recommend the MOOC “Cybersecurity and the Internet of Things” (external content). Figure 49 gives an overview of the content, which is available in the categories “Introduction”, “Deep Dive”, and “Special Topics” for this learning journey.

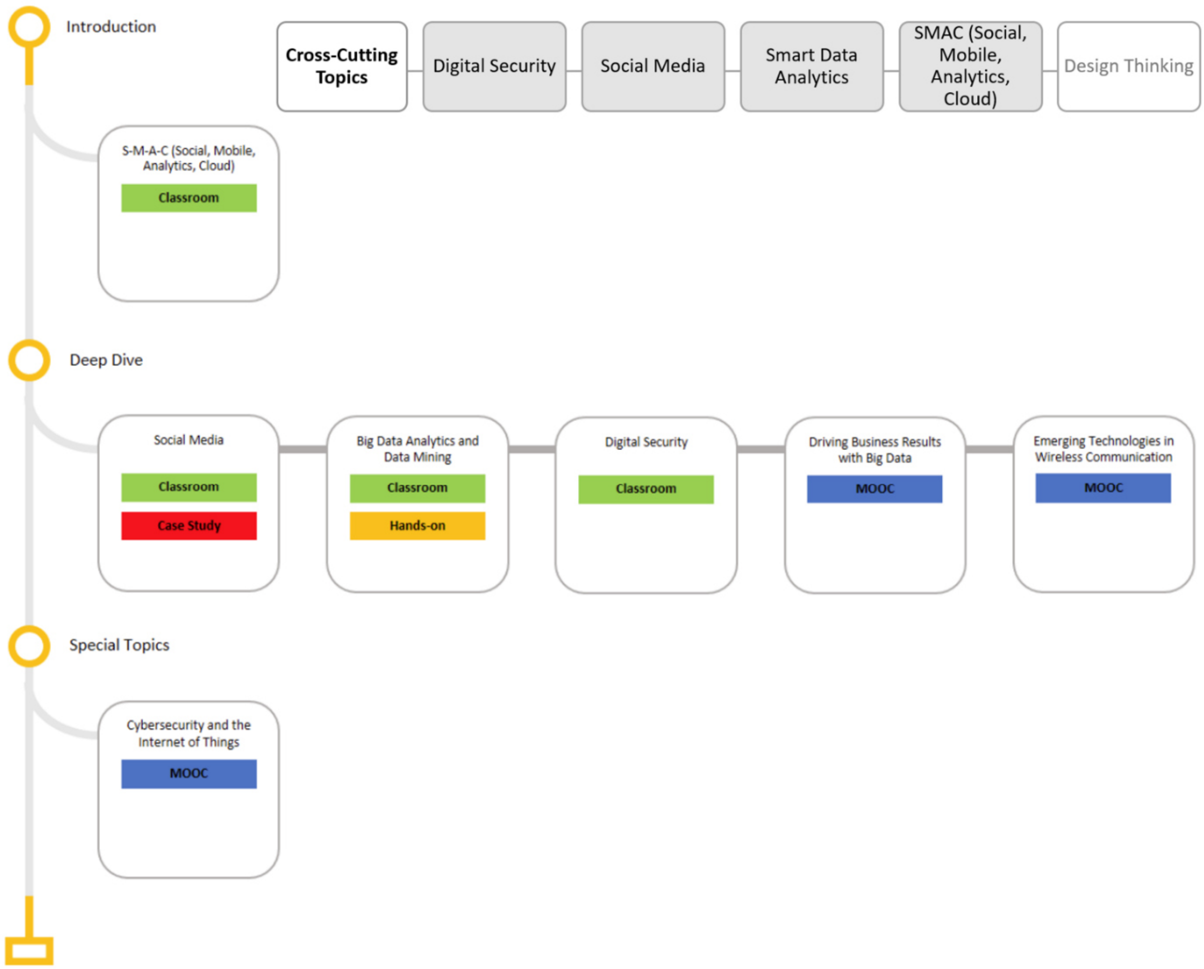


Figure 49: Learning Journey "Cross-Cutting Topics" (screenshot from curriculum "The Digital Transformation of Global Bike", provided by SAP UCC Munich (2017a))

5.6.1.7 Learning Journey "Digital Innovation"

As mentioned earlier, one of the characteristics of Industry 4.0 are new or enhanced technologies. These can lead to new business models. Therefore, it is important for companies to adjust their business to Industry 4.0 – and maybe even to develop new products and services, they have to conduct digital innovations. The learning journey "Digital Innovation" offers a deep dive into this topic. Table 64 contains the content and advices of how to use the learning journey, as well as the target audience of this learning journey.

Table 64: Learning Journey "Digital Innovation"

Learning Journey "Digital Innovation"	
Description	*"This learning journey provides a closer look at the [d]igital [i]nnovation. It starts with an introduction [m]odule, ["]Digital Innovation Management["], including theory aas [sic!] well as exercises and case studies. For a deep dive to [!] the topic[,] we suggest the module ["]Design Thinking[" ,] that can be conducted as a workshop for generating new innovative ideas. As a further deep dive [...][,] students can follow the MOOCs ["]Innovation Management["] and ["]Innovation in a Digital World["]. For students with special interest on [sic!] the topic[,] we suggest the special topic MOOCs ["]Leadership in Digital Transformation["], ["]Design Thinking for Innovation[" ,] as well as ["]Developing Software Using Design Thinking["]."* (SAP UCC Munich, 2017l).
Target Audience	*"[S]tudents of all study disciplines and level including Information Systems, Informatics, Engineering[,] and Economics that are interested in topics of innovation and innovation creation and management"* (SAP UCC Munich, 2017l)

As introduction to this learning journey, we propose the curriculum module "Digital Innovation Management". Based on our experiences with Design Thinking during the curriculum development project, we offer the curriculum module "Design Thinking" from the cross-cutting topics section as deep dive as it can support the creative innovation process. Further deep dives are the MOOCs "Innovation Management" (external content) and "Innovation in a Digital World" (external content), which both comprise a more strategical view on digital innovation. In the special topics, we offer two more MOOCs connected to Design Thinking: "Design Thinking for Innovation" (external content) and "Developing Software using Design Thinking" (external content). In addition, there is another MOOC with strategic content: "Leadership in Digital Innovation" (external content). Figure 50 gives an overview of the content, which is available in the categories "Introduction", "Deep Dive", and "Special Topics" for this learning journey.

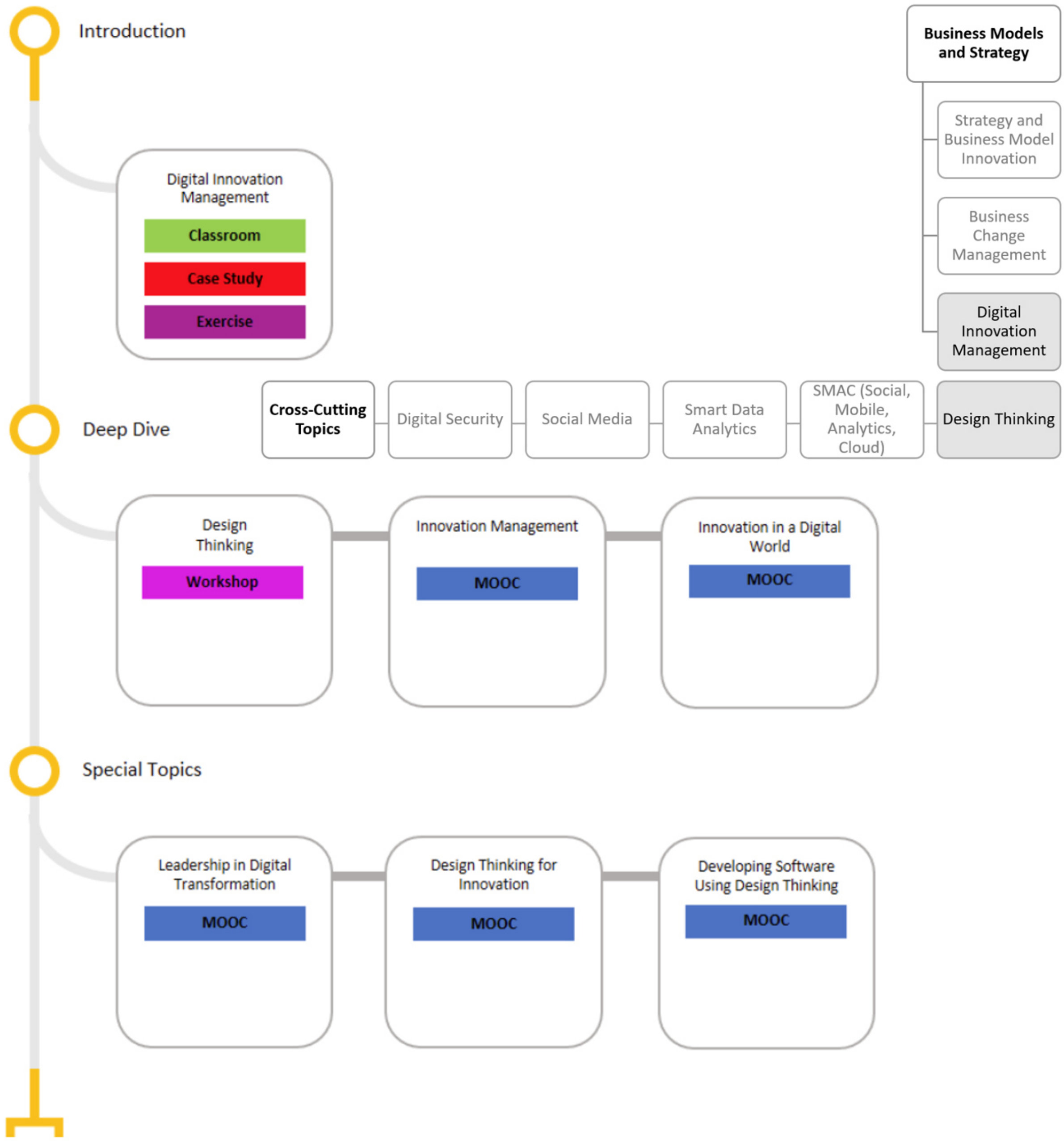


Figure 50: Learning Journey "Digital Innovation" (screenshot from curriculum “The Digital Transformation of Global Bike”, provided by SAP UCC Munich (2017g))

5.6.1.8 Learning Journey “IoT and Data Analytics”

The learning journey “IoT and Data Analytics” focusses on new IoT technologies such as sensors in combination with the analysis of the data generated by those technologies. Table 65 contains the content and advices of how to use the learning journey, as well as the target audience of this learning journey.

Table 65: Learning Journey "IoT and Data Analytics"

Learning Journey “IoT and Data Analytics”	
Description	*“This learning journey provides a closer look [at] the combination of IoT and [d]ata [a]nalytics. It starts with the module [“]IoT: Integrating Sensors[” ,] which offers an introduction to the topics of IoT and sensors in IoT. Through hands-on exercises[,] students can apply theior [sic!] knowledge in practice by using software [such] as SAP HANA and hardware [such] as Rasberry [sic!] Pi in order to generate sensor data. For a deep dive[,] we recommend the module [“]Smart Data Analytics[” ,] that give [sic!] students the possibility to further analyse the generated sensor data. Online available MOOCs [such] as [“]Getting Started with Data Science[”], [“]Imagine IoT[”], and [“]How the Internet of Things and Smart Services will Change Society[”] can be conducted for a deeper and better knowledge on the topic. For students with special interest on the topic[,] we also recommend the MOOCs [“]Enterprise Machine Learning in a Nutshell[”], [“]Text Analytics with SAP HANA Platform[“ ,] and [“] Cyberseurty [sic!] and the Internet of Things[”].”*(SAP UCC Munich, 2017l).
Target Audience	*“[S]tudents of Information Systems, Informatics[,] and Engineering[.] in their [b]achelor or [m]aster studies, interested in topics of IoT, [s]ensors [sic!] [d]ata[,] and [a]nalytics”* (SAP UCC Munich, 2017l)

As introduction, we propose the curriculum module “IoT: Integrating Sensors”. After that, we recommend as deep dive into analytics the curriculum module “Smart Data Analytics” and the MOOC “Getting Started with Data Science” (external content). The MOOCs “Imagine IoT” (external content) and “How the Internet of Things and Smart Services will Change Society” (external content) offer further deep dives. As special topics, we propose two analytics-related MOOCs: “Enterprise Machine Learning in a Nutshell” (external content) and “Text Analytics with SAP HANA Platform” (external content). The MOOC “Cybersecurity and the Internet of Things” (external content) creates awareness for security threats in IoT. Figure 51 gives an overview of the content, which is available in the categories “Introduction”, “Deep Dive”, and “Special Topics” for this learning journey.

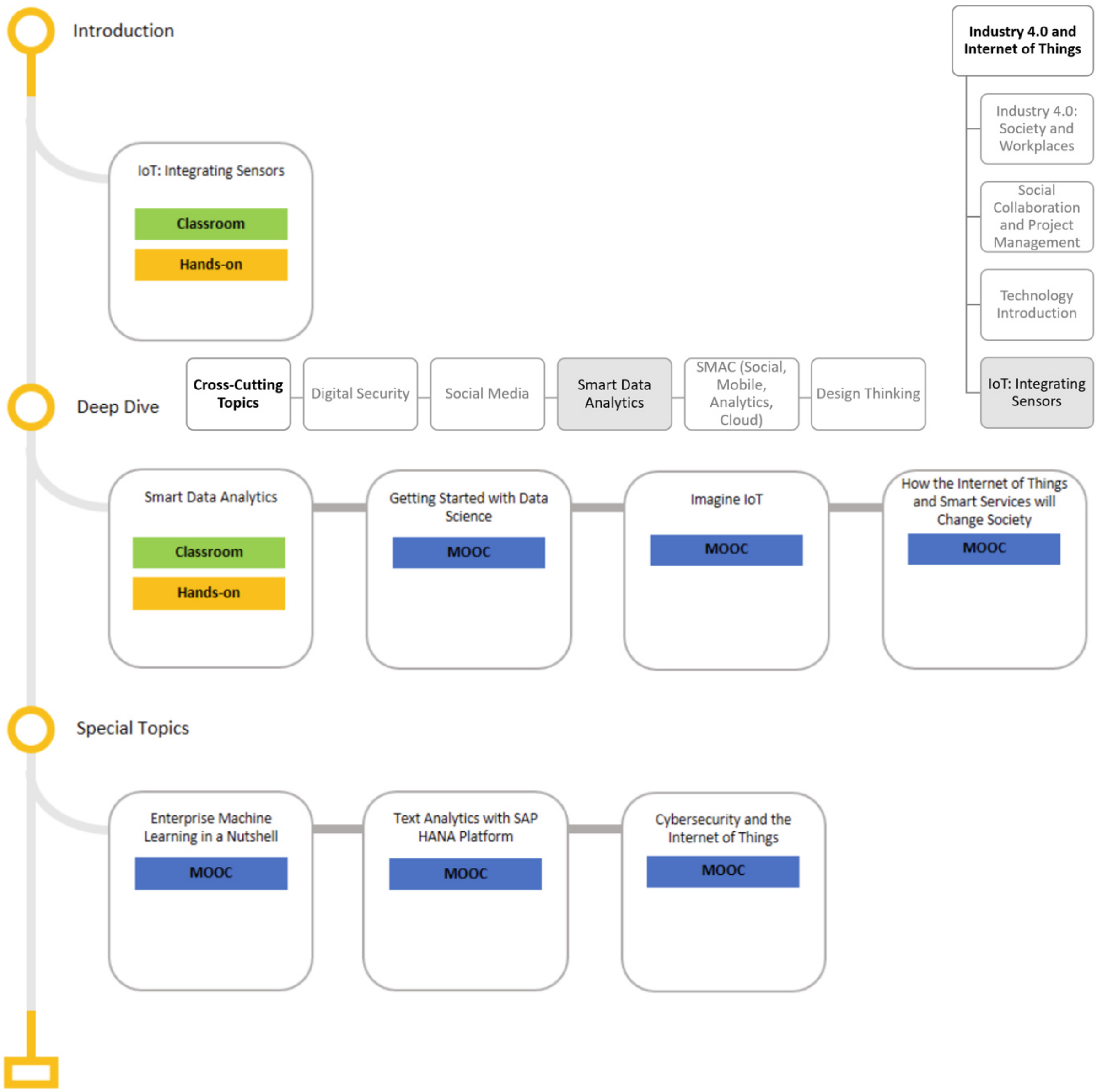


Figure 51: Learning Journey "IoT and Data Analytics" (screenshot from curriculum “The Digital Transformation of Global Bike”, provided by SAP UCC Munich (2017j))

5.6.2 Evaluation of Learning Journeys

The concept of the learning journeys was presented in the “breakout sessions” at the 22nd SAP Academic Conference EMEA on September 12th, 2017 in Karlsruhe, Germany (cp. section 5.2.2). The participants rated the learning journeys for specific topics with 4.3 points out of 5, which is a positive result. One participant rated the learning journeys as “very important as an educational method”. The pilot customers (cp. section 5.2.3) rated the integration of learning journeys with 4.5 points out of 5. One lecturer wishes for learning journeys that follow whole processes end-to-end. This point is added to the bugs and enhancement list for a possible second release of the curriculum. Another pilot customer wishes for a complete empty SAP S/4HANA system where he can start from scratch with customizing and entereing data.

5.7 Integrating Interactive and Supporting Elements and Materials

To support lecturers and trainers in building an activating learning experience for their learners and trainees, we integrated interactive and supporting elements to our curriculum. They will be introduced in the following sections. Check-Your-Knowledge-Slides, onlineTED, and Answer-Garden can be used in classes. We implemented a Course Calculator to support the instructor in tailoring the content for his lecture. The goal of the Glossary and the List of Abbreviation contained in the curriculum is to support the lecturer on the one hand. On the other hand, they can be offered to the participants as supportive materials during their learning processes.

We strongly advise lecturers to make themselves familiar with any tool before using it in class to avoid frustrating situations in classes. To make it easier for lecturers to integrate the interactive elements we implemented in our curriculum into their lectures, we added lecturer notes for the tools onlineTED (Knigge, 2017b) and AnswerGarden (Knigge, 2017a). These lecturer notes include all information needed to use onlineTED or AnswerGarden, starting from creating an account (onlineTED) to a detailed description over how to use onlineTED or AnswerGarden in class to the display and analysis of results.

As one example for interactive elements, the tool onlineTED and our idea of how to use it in the scope of the curriculum was presented and discussed in the "breakout sessions" at the 22nd Academic Conference EMEA 2017 (cp. section 5.2.2). The integration of the onlineTED was rated with an average of 4.3 out of 5 in the questionnaires, a positive result. One participant stated that "It is a nice tool[,] it sometimes […] can […] create atmosphere". Another one stated that he would even like to go further and prefer to use a more complex tool with more functions.

5.7.1 Check-Your-Knowledge Slides

Many of the slide decks of the prototype curriculum contain "Check-Your-Knowledge" slides. These series of slides always start with an introduction slide as presented in Figure 52. On the next slide(s), questions regarding the content presented in the previous slides are given (cp. Figure 53). After this section, there is the "Solutions" introduction slide (cp. Figure 54) followed by the slide(s) that contain(s) the questions given before together with the corresponding solutions (cp. Figure 55). These "Check-Your-Knowledge" slides can be used in classes to repeat the content – and to get a first impression if the participants gained an understanding of the topics at hand. Templates of the "Check-Your-Knowledge" slides are included in the slide deck "Control Questions, Votes, Brainstorming – Layout" (SAP UCC Munich, 2017d) in order to enable lecturers and instructors to add more "Check-Your-Knowledge" sections containing their own questions.

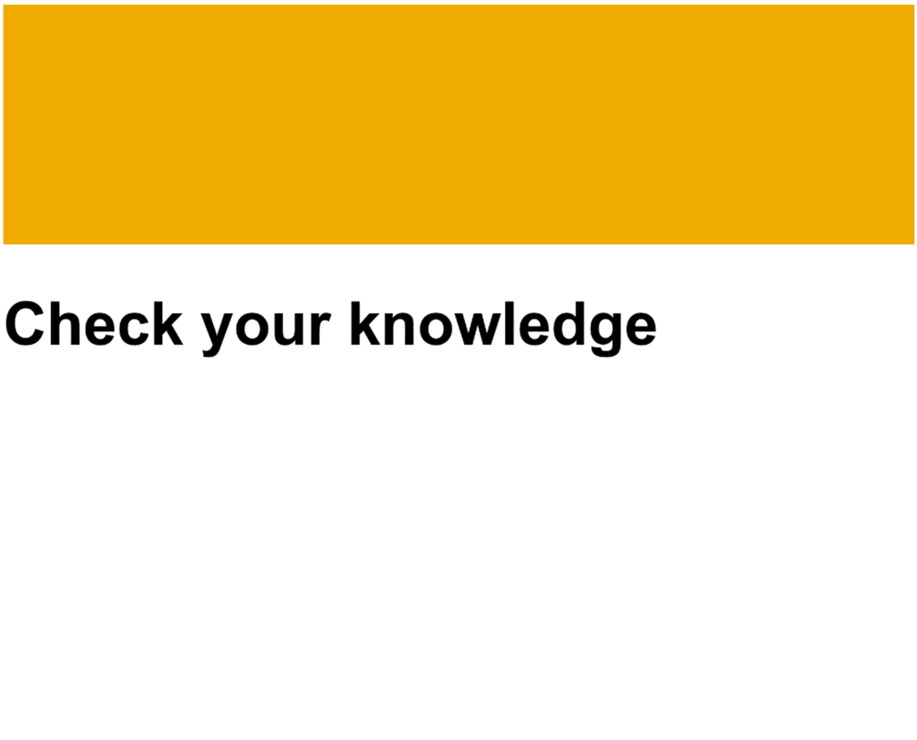


Figure 52: Introduction Slide to "Check-Your-Knowledge" Section (screenshot from the slide deck "Control Questions, Votes, Brainstorming – Layout" of the prototype curriculum "The Digital Transformation of Global Bike" (SAP UCC Munich, 2017d, p. 1))

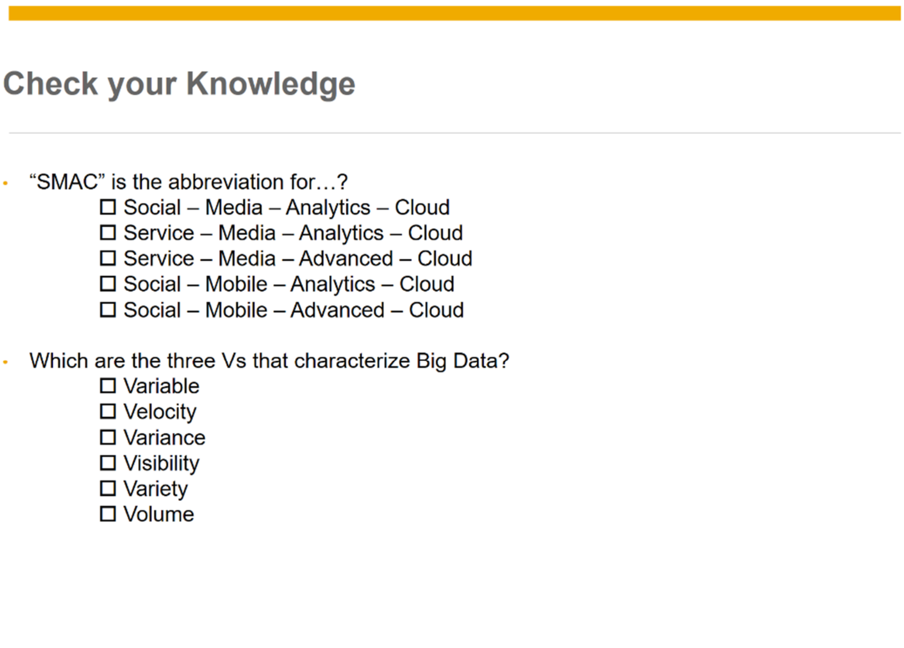


Figure 53: Example Questions in "Check-Your-Knowledge" Section (screenshot from the slide deck "Control Questi-ons, Votes, Brainstorming – Layout" of the prototype curriculum "The Digital Transformation of Global Bike" (SAP UCC Munich, 2017d, p. 2))

Figure 54: Introduction Slide to Solutions in "Check-Your-Knowledge" Section (screenshot from the slide deck "Control Questions, Votes, Brainstorming – Layout" of the prototype curriculum "The Digital Transformation of Global Bike" (SAP UCC Munich, 2017d, p. 3))

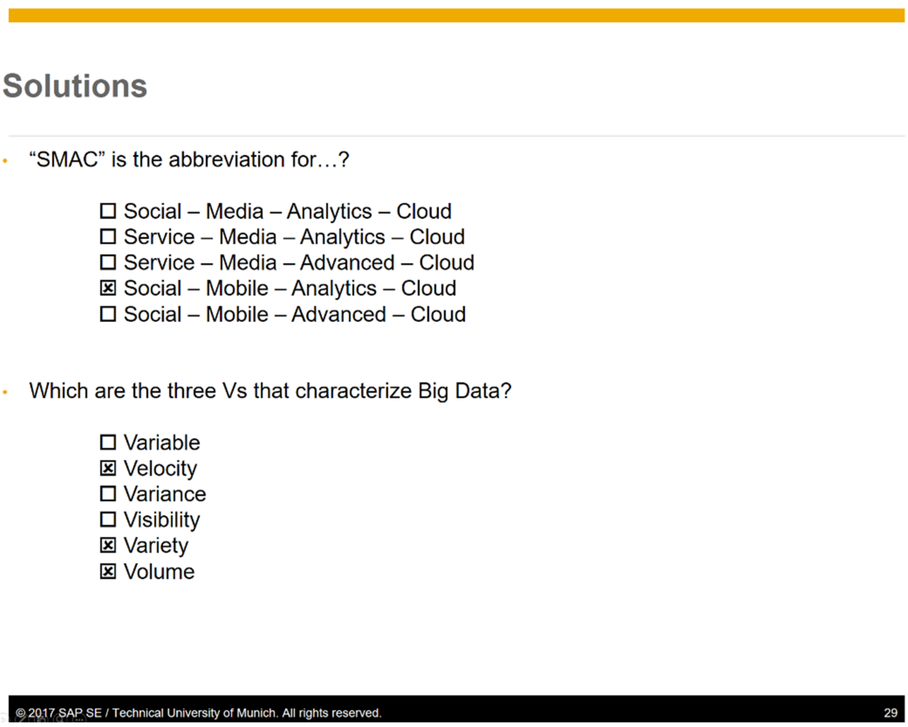


Figure 55: Example Solutions Slide in "Check-Your-Knowledge" Section (screenshot from the slide deck "Control Questions, Votes, Brainstorming – Layout" of the prototype curriculum "The Digital Transformation of Global Bike" (SAP UCC Munich, 2017d, p. 4))

5.7.2 Discussion Slides

In many of the slide decks of the prototype curriculum, we integrated “Discussion” slides. These slides are recognizable by the layout presented in Figure 56. They contain questions regarding the topic that has been presented in the previous slides. The questions are presented in a yellow box. The lecturer or instructor can discuss these questions in class. In the prototype curriculum, sample solutions for these discussion slides are not provided. A template “Discussion” slide is included in the slide deck “Control Questions, Votes, Brainstorming – Layout” (SAP UCC Munich, 2017d) in order to enable lecturers and instructors to add more “Discussion” slides containing their own questions.

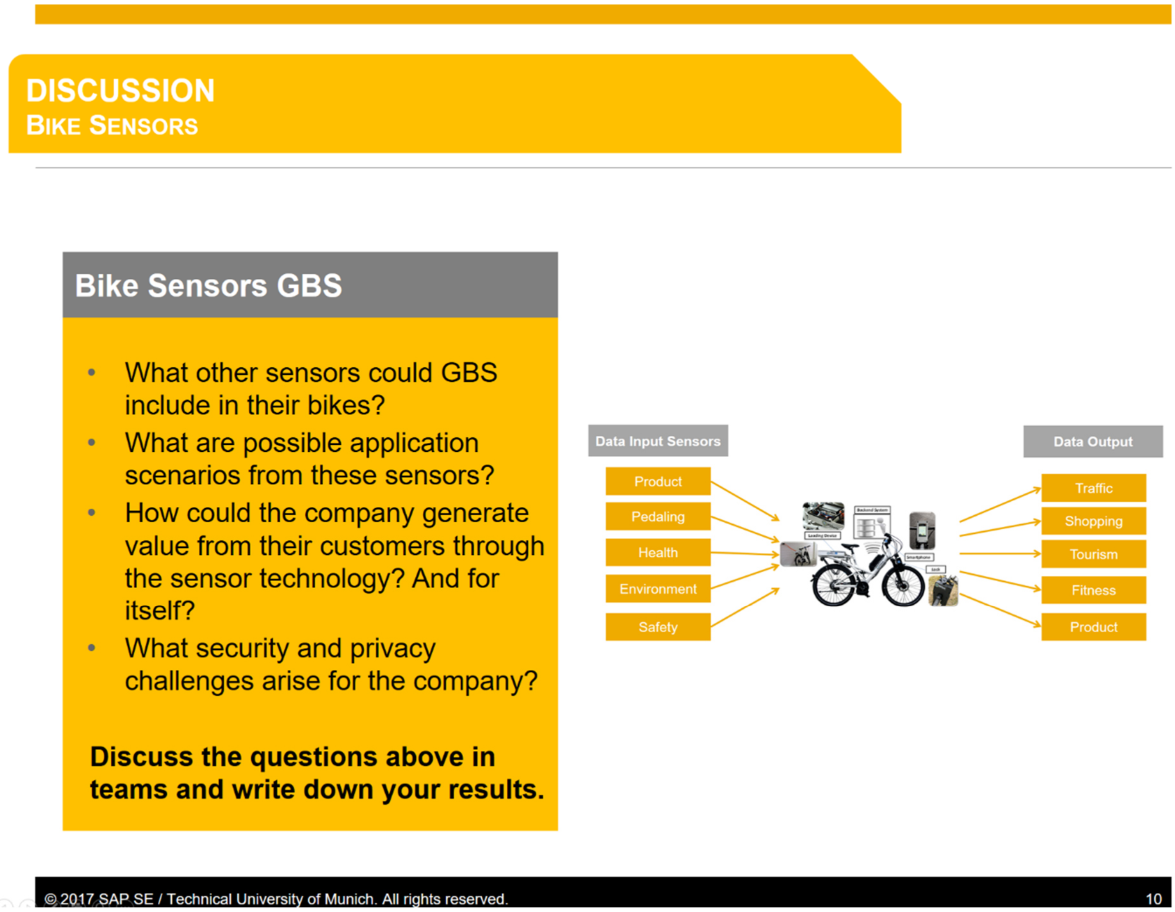


Figure 56: Example Discussion Slide (screenshot from the slide deck “Control Questions, Votes, Brainstorming – Layout” of the prototype curriculum “The Digital Transformation of Global Bike” (SAP UCC Munich, 2017d, p. 10))

5.7.3 onlineTED

onlineTED[72] is a freely available tool, which can be used for interactive votes in classes. The lecturer or instructor can ask questions; students or participants can answer them using their mobile devices such as laptops, tablets, or mobile phones. To use onlineTED, the lecturer has to create an account – which is freely available. After that, the tool can be used immediately to ask questions. He can project a Quick Response (QR) code to a wall or hand over the link www.onlineted.com together with an access code to the participants. With these access tokens, they can respond to his questions immediately. The results can be displayed in class in real-time. An example for an onlineTED question from the participants view is given in Figure 57.

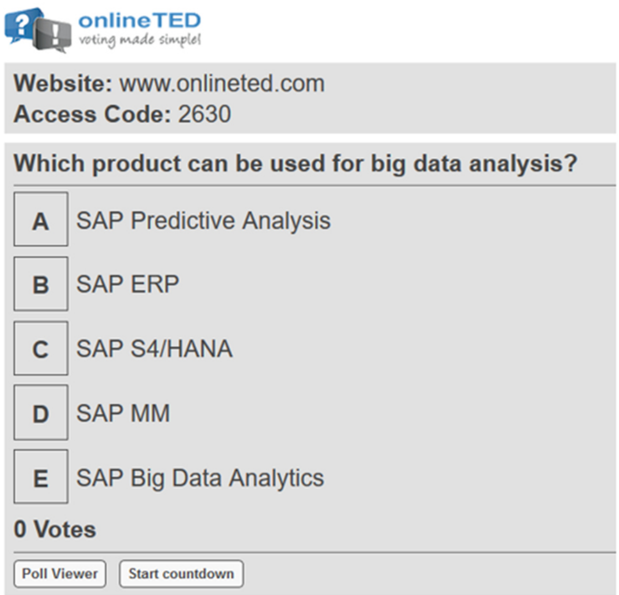
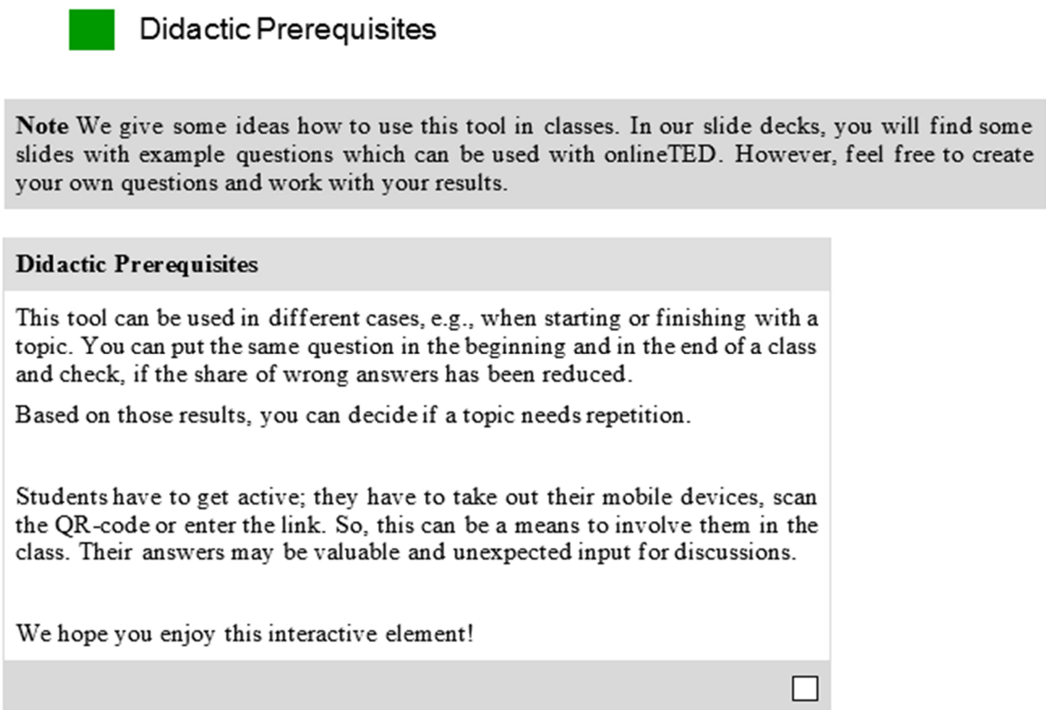


Figure 57: onlineTED: Example Question (screenshot taken from Lecturer Notes (Knigge, 2017b))


Didactic Prerequisites

Note We give some ideas how to use this tool in classes. In our slide decks, you will find some slides with example questions which can be used with onlineTED. However, feel free to create your own questions and work with your results.

Didactic Prerequisites

This tool can be used in different cases, e.g., when starting or finishing with a topic. You can put the same question in the beginning and in the end of a class and check, if the share of wrong answers has been reduced.

Based on those results, you can decide if a topic needs repetition.

Students have to get active; they have to take out their mobile devices, scan the QR-code or enter the link. So, this can be a means to involve them in the class. Their answers may be valuable and unexpected input for discussions.

We hope you enjoy this interactive element!

Figure 58: Didactical Prerequisites for onlineTED (screenshot taken from Lecturer Notes (Knigge, 2017b))

[72] onlineTED: Voting tool. https://www.onlineted.de/index.php. Accessed on July 31st, 2017.

In several of the slide decks of the prototype Industry 4.0 curriculum, we integrated slides with example questions that can be used with onlineTED. In the lecturer notes, we encourage lecturers to create and apply their own questions and use the results in their classes. An example is given in Figure 58. Figure 59 and Figure 60 show an example of our onlineTED-slides in the slide deck "SMAC – 3rd Platform" of the prototype curriculum "The Digital Transformation of Global Bike" (Knigge, 2017c). The lecturer can use these as is – or add their own questions after they gained some experience with onlineTED. Templates of "Time-to-VOTE" slides are included in the slide deck "Control Questions, Votes, Brainstorming – Layout" (SAP UCC Munich, 2017d).

Figure 59: Introduction Slide to onlineTED Question(s) (screenshot from the slide deck "SMAC – 3rd Platform" of the prototype curriculum "The Digital Transformation of Global Bike" (Knigge, 2017c))

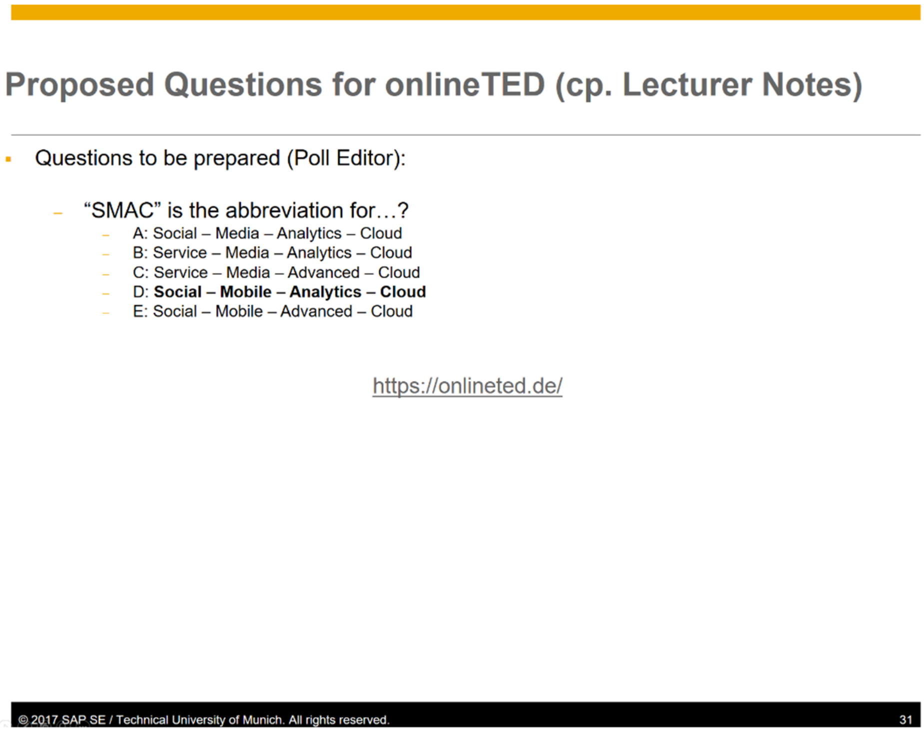


Figure 60: Example Questions for onlineTED (screenshot from the slide deck "SMAC – 3^{rd} Platform" of the prototype curriculum "The Digital Transformation of Global Bike" (Knigge, 2017c))

5.7.4 AnswerGarden

AnswerGarden[73] is a freely available tool, which can be used for interactively collecting feedback or for interactive brainstorming in classes. The lecturer or instructor can ask questions; students or participants can answer using their mobile devices such as laptops, tablets, or mobile phones. The answers can be collected and displayed on a screen in real-time. AnswerGarden is available free without the need to create any accounts. On the homepage of AnswerGarden, the lecturer has to choose "Create AnswerGarden". Next, he can put in a topic or a question and choose the mode for this execution:

- "Brainstorming: Each of the students can submit an unlimited number of answers. The same answer can be submitted several times.
- Classroom: Each of the students can submit an unlimited number of answers. The same answer cannot be submitted more than once.
- Moderator: Each answer has to be approved manually by the instructor.
- Locked: No answers can be submitted." (Knigge, 2017a, p. 3)

Next, the lecturer can decide, if the answers of the participants should be limited to twenty or forty characters. He can assign an administrator password to his question for being able to enter it later again. He can enter an email address to be able to reset his password. The question can then be started. The URL of the started question contains the ID of the question. This ID has to

[73] AnswerGarden: Feedback and brainstorming tool. https://answergarden.ch/. Accessed on July 31^{st}, 2017.

be handed over to the participants, as they need it in oder to access the question. Alternatively, a QR code can be projected to a wall. Moreover, with AnswerGarden, it is possible to share the question via different social media channels, such as Twitter or facebook. This way, the participants can access and respond to the question immediately. An example for an AnswerGarden question from the participants view is given in Figure 61. In this example, the ID of the question is 750452 – as displayed in the URL.

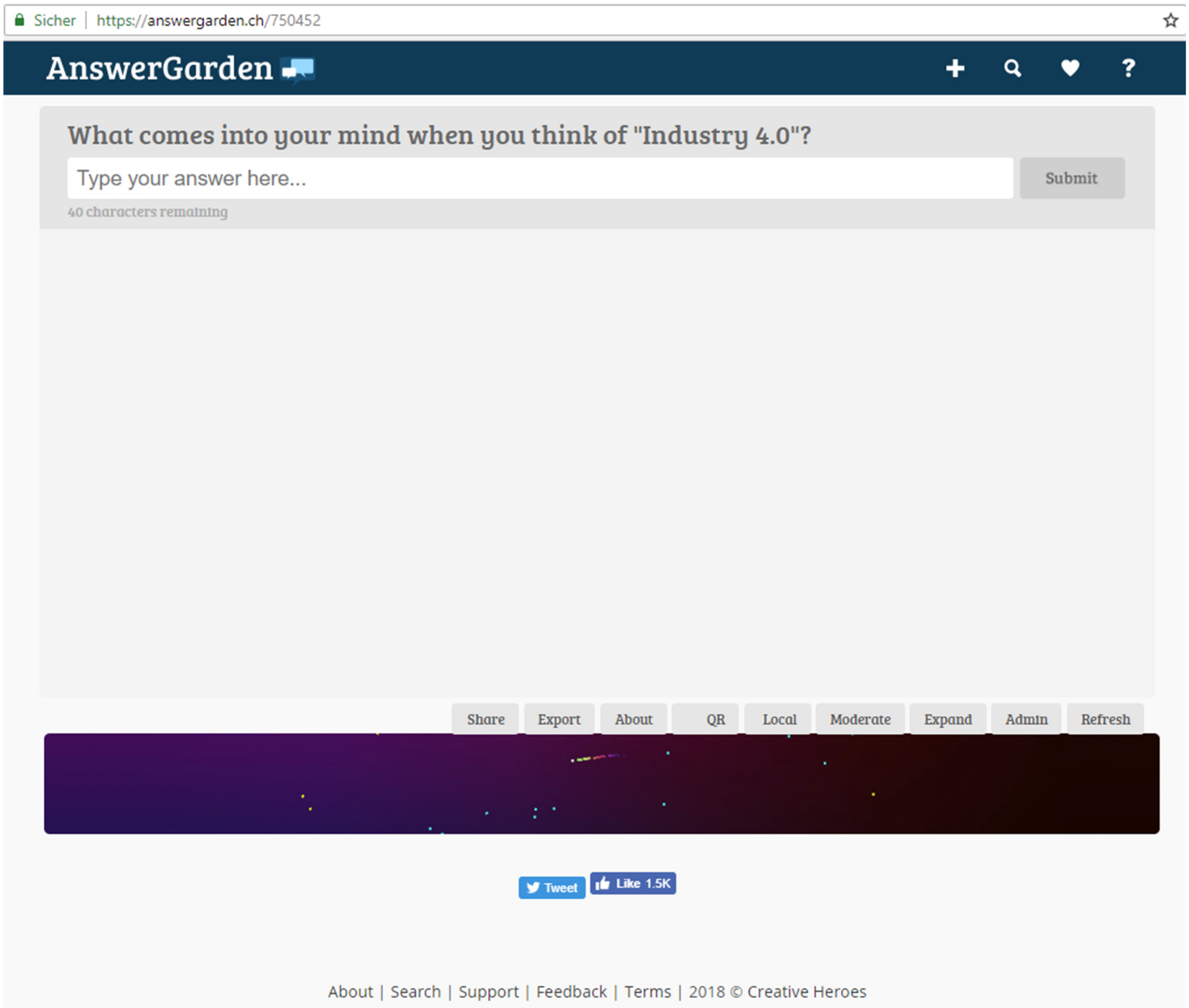


Figure 61: AnswerGarden Example Question (screenshot taken from https://answergarden.ch/)

In several of the slide decks of the prototype Industry 4.0 curriculum, we integrated slides with example questions that can be used with AnswerGarden. In the lecturer notes, we encourage lecturers to create and apply their own questions and use the results in their classes.

Figure 62 and Figure 63 show an example of our AnswerGarden-slides in the slide deck "Control Questions, Votes, Brainstorming – Layout" of the prototype curriculum "The Digital Transformation of Global Bike" (SAP UCC Munich, 2017d). The lecturer can use these as template and add their own questions.

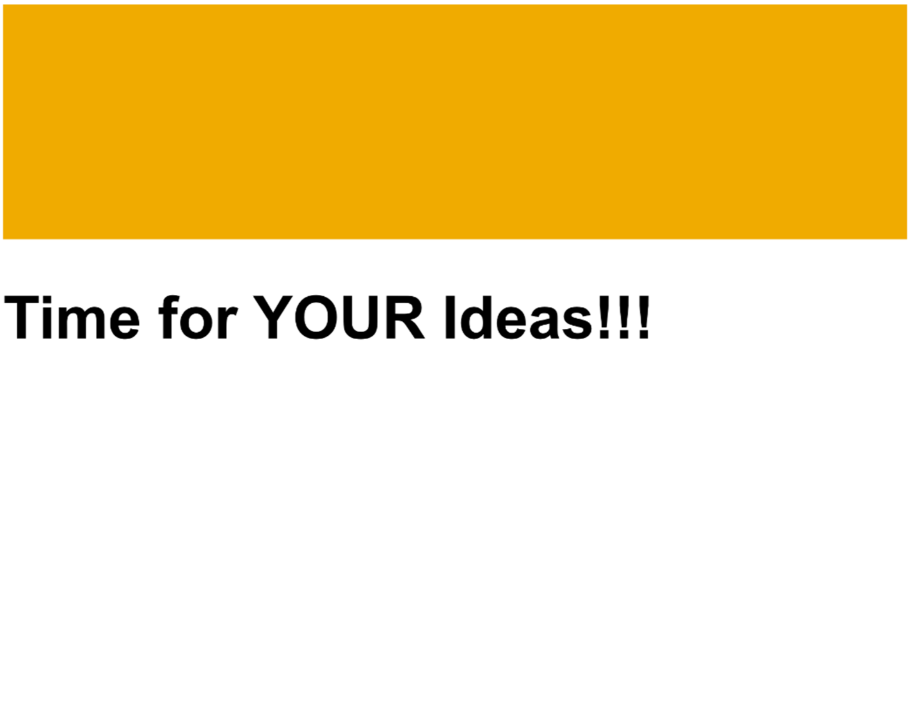


Figure 62: Introduction Slide to AnswerGarden Question(s) (screenshot from the slide deck “Control Questions, Votes, Brainstorming – Layout” of the prototype curriculum “The Digital Transformation of

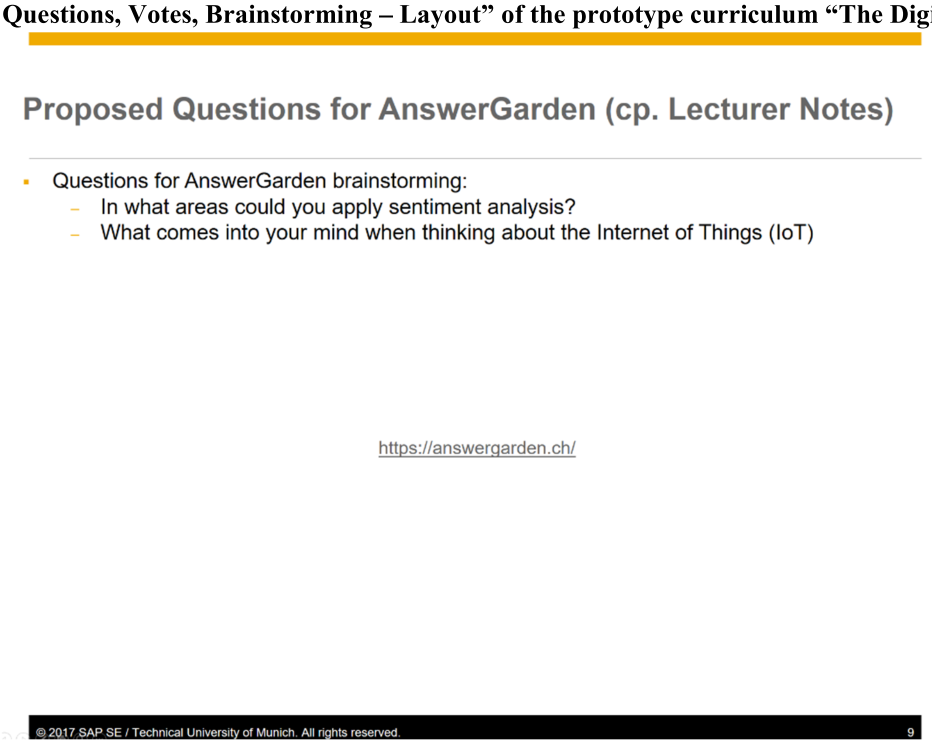


Figure 63: Example Questions for AnswerGarden (screenshot from the slide deck “Control Questions, Votes, Brainstorming – Layout” of the prototype curriculum “The Digital Transformation of Global Bike” (SAP UCC Munich, 2017d, p. 9))

5.7.5 Course Calculator

One aspect included in the feedback of potential curriculum users and customers provided in the "breakout sessions" (cp. section 5.2.2) was that is a challenge to decide how much content can be provided and has to be prepared for a given amount of time, e.g., for one lecture in one term. For example, this may comprise $2 \times 90\ minutes \times 14\ weeks$. This comes up to 2,520 minutes – or 42 hours, which need to be filled with enough – but not too much – content. Our lecturers expressed their difficulties to calculate this – especially with materials they did not produce themselves. As we had discussed this issue before, we were able to present a solution for this issue already in the "breakout sessions" – it was already prepared for evaluation.

In the curriculum development project, we implemented a feature that allows lecturers or trainers to choose elements from the curriculum "The Digital Transformation of Global Bike", and then to receive a projection of how much time they can cover with the materials chosen. As the main task of this feature is to calculate the duration of the materials for a special course, it is called "Course Calculator". The Course Calculator is included in the Curriculum Navigation Application (cp. section 5.4), so that it is easily accessible to all curriculum users. Figure 64 shows the landing page of the Course Calculator.

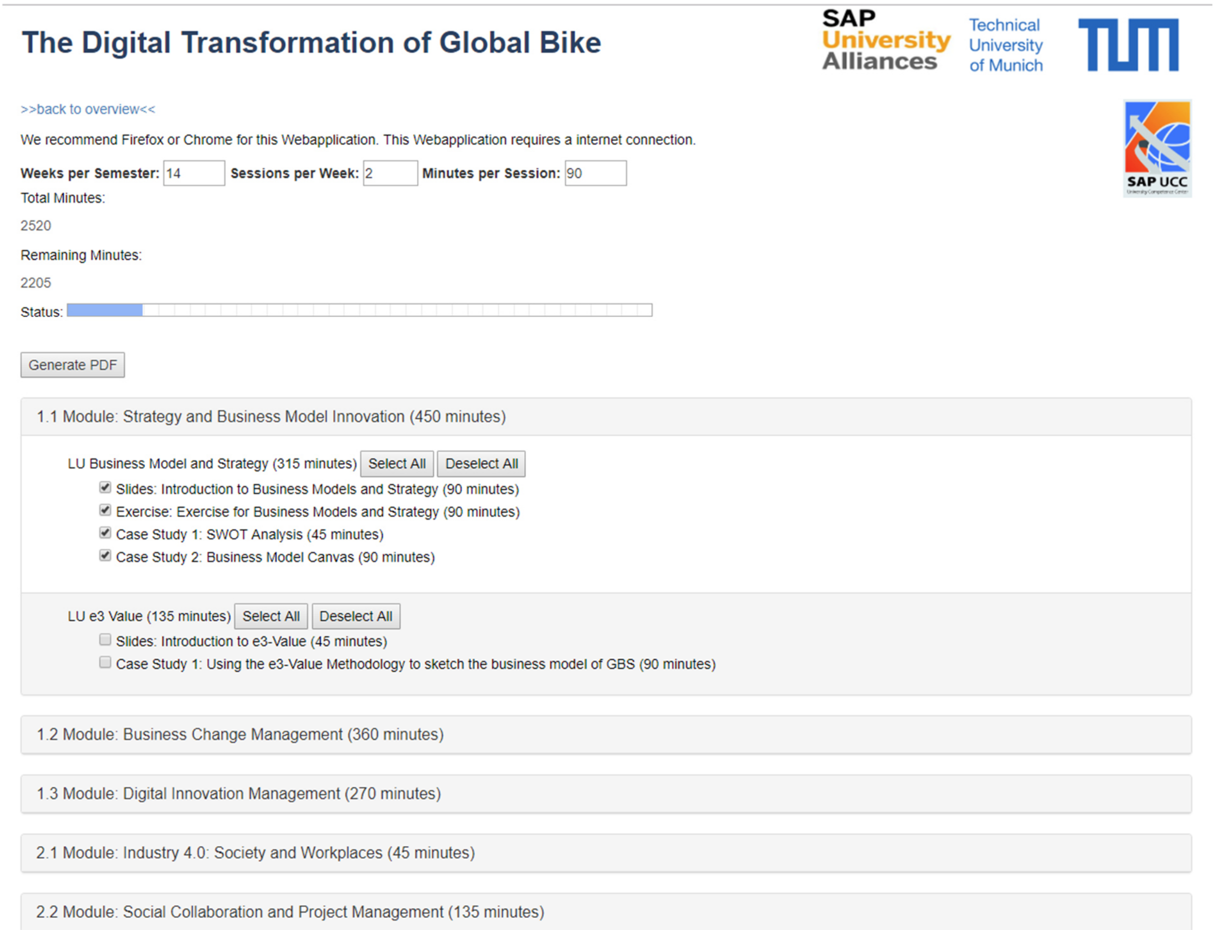


Figure 64: Course Calculator (screenshot from curriculum "The Digital Transformation of Global Bike", provided by SAP UCC Munich (2017e))

In the second row, the user can enter the time frame of the lecture he wants to plan. Therefore, he has to enter the weeks per semester (or term), the number of sessions per week, and the amounts of minutes per session (e.g., 45 minutes, 60 minutes, or 90 minutes). Based on this, the Course Calculator computes the total amount of minutes of the lecture. This is displayed as "Total Minutes". Below this entry, the "Remaining Minutes" are shown which are calculated as $Total\ Minute\ - duration\ of\ elements\ chosen$. The status bar gives a visual indication of how much of the time of the lecture has already been filled by the elements chosen so far (cp. Figure 64).

Below, there is a bar for each module of the curriculum, e.g., "1.1 Module: Strategy and Business Model Innovation (450 minutes)", or "1.2 Module: Business Change Management (360 minutes)" (cp. Figure 64). When clicked on, these bars expand. The learning units included are shown, e.g. for module 1.1 "LU Business Model and Strategy (315 minutes)" and "LU e3 Value (135 minutes)". For each learning unit, there is a list of the single materials included, each of these tagged with the estimated duration. E.g., for "LU e3 Value (135 minutes)", there are the following materials available: "Slides: Introduction to e3-Value (45 minutes", and "Case Study 1: Using the e3-Value Methodology to sketch the business model of GBS (90 minutes)" (cp. Figure 64). The user can choose single materials by ticking the checkboxes, or he can select or deselect learning units as a whole by clicking on the corresponding "Select All" or "Deselect All" button. After the user is finished with his selection of materials, he can generate a PDF file by pressing the button "Generate PDF" in the Course Calculator. He receives a PDF file containing all chosen elements including the indication for their duration. An example is shown in Figure 65.

Digital Transformation of Global Bike - Your Course Selection

Weeks: 14 22.5.2018
Sessions per Week: 2
Minutes per Session: 90
Total Minutes available: 2520

Selected Courses:

1.1 Module: Strategy and Business Model Innovation
  Slides: Introduction to Business Models and Strategy (90 minutes)
  Exercise: Exercise for Business Models and Strategy (90 minutes)
  Case Study 1: SWOT Analysis (45 minutes)
  Case Study 2: Business Model Canvas (90 minutes)

1.2 Module: Business Change Management
  -

1.3 Module: Digital Innovation Management
  -

2.1 Module: Industry 4.0: Society and Workplaces
  -

2.2 Module: Social Collaboration and Project Management
  -

Figure 65: Course Calculator: PDF list with Elements Chosen for Lecture (screenshot from curriculum "The Digital Transformation of Global Bike", provided by the SAP UCC Munich: Project Curriculum Development (2016 - 2017))

As mentioned before, the Course Calculator was presented and evaluated in the "breakout sessions" (cp. section 5.2.2). The participants rated it with 4.1 points out of 5, a good result.

5.7.6 Glossary

From our experiences in teaching and learning, we know that from time to time people come to a point that they have learned about a concept, but they need a short reminder to be able to retrieve their knowledge. Therefore, we decided to add a glossary to our Curriculum Navigation Application. This glossary is built as alphabetically arranged subject catalogue. The overview of the landing page is shown in Figure 66.

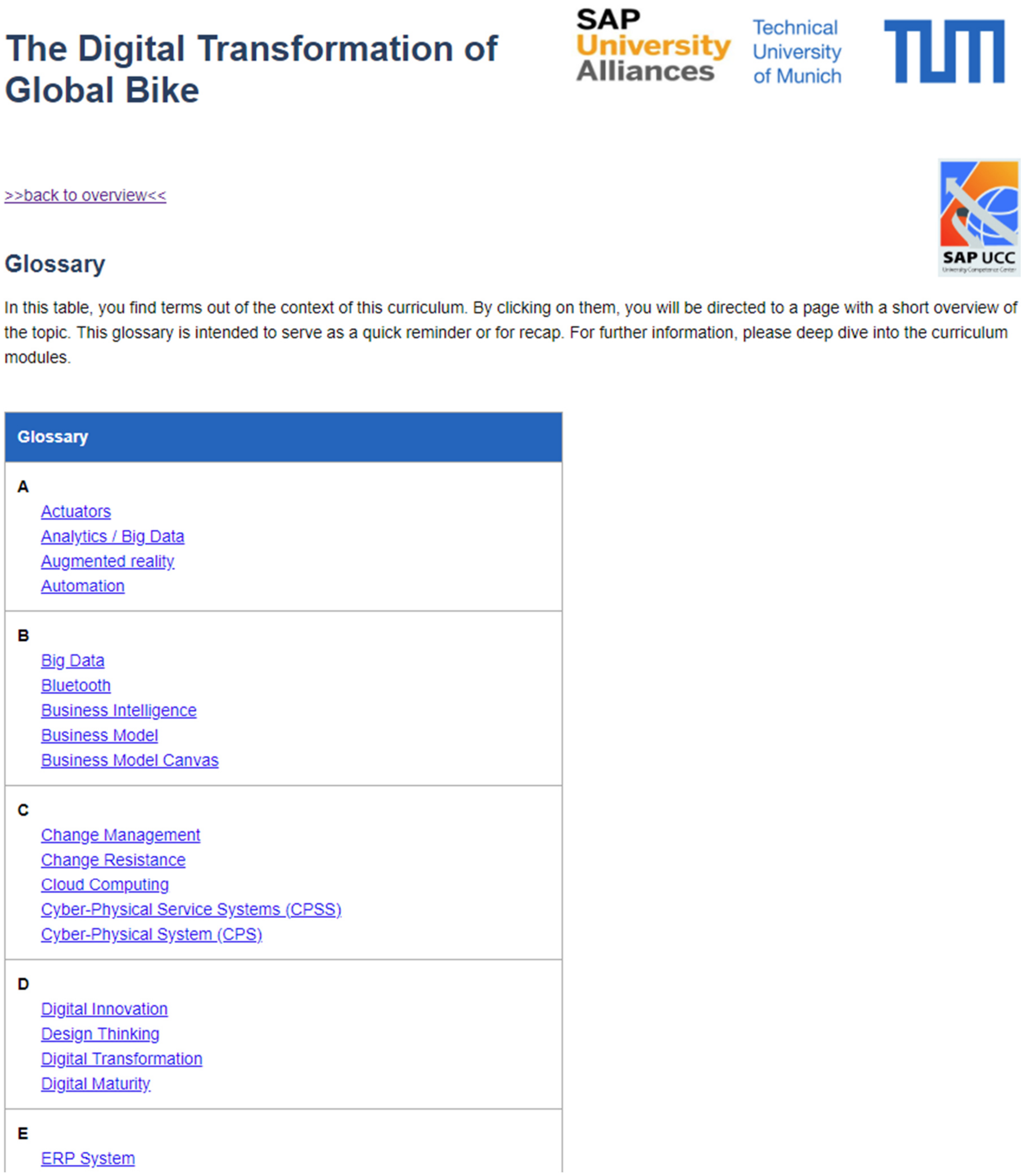
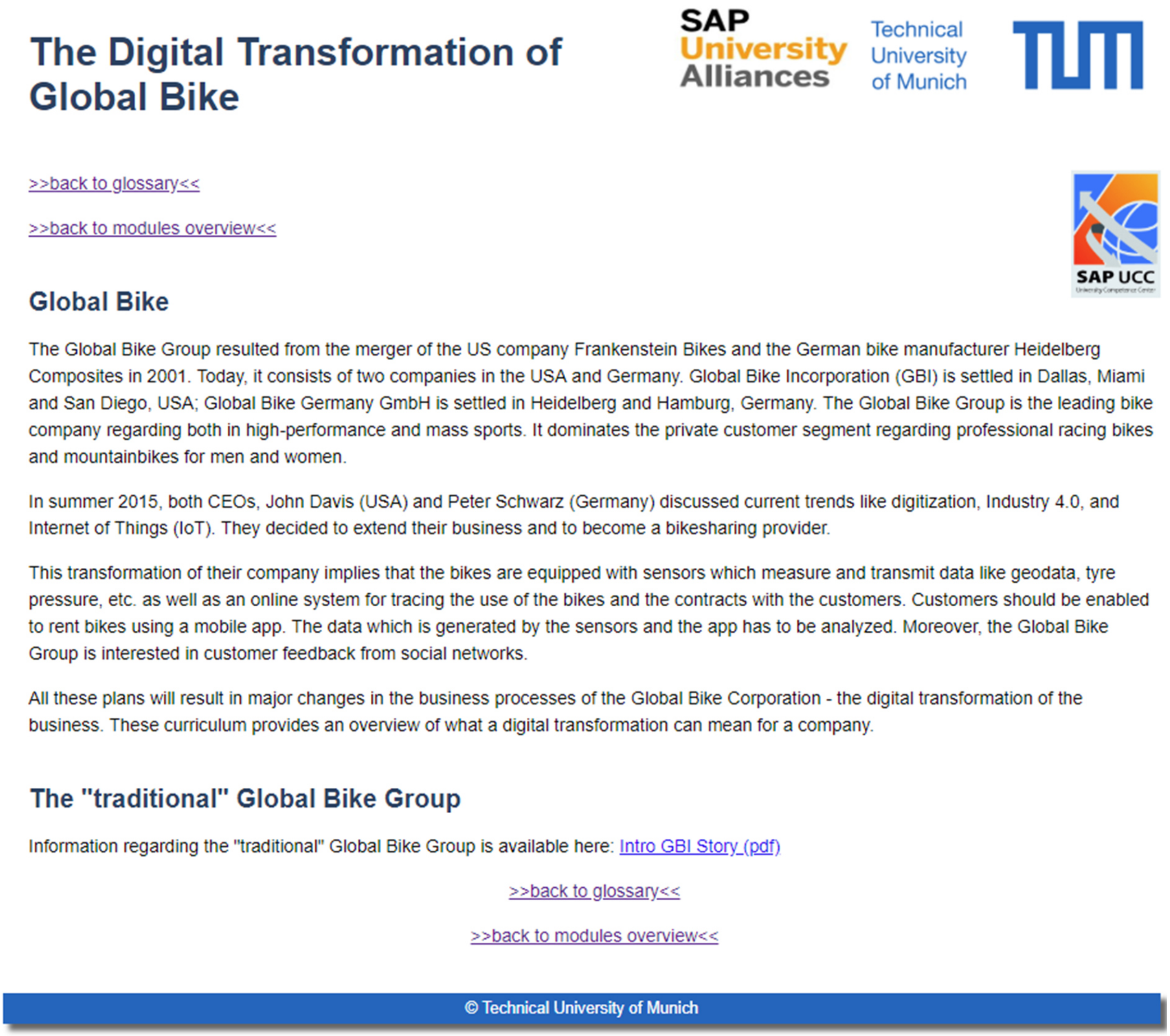


Figure 66: Glossary: Landing Page (screenshot from curriculum "The Digital Transformation of Global Bike", provided by the SAP UCC Munich: Project Curriculum Development (2016 - 2017))

If the user clicks on one of the items, he is directed to a page with short information regarding the subject chosen. Figure 67 shows the item entry for the example “Global Bike”.


The Digital Transformation of Global Bike

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>>back to glossary<<

>>back to modules overview<<

SAP UCC

Global Bike

The Global Bike Group resulted from the merger of the US company Frankenstein Bikes and the German bike manufacturer Heidelberg Composites in 2001. Today, it consists of two companies in the USA and Germany. Global Bike Incorporation (GBI) is settled in Dallas, Miami and San Diego, USA; Global Bike Germany GmbH is settled in Heidelberg and Hamburg, Germany. The Global Bike Group is the leading bike company regarding both in high-performance and mass sports. It dominates the private customer segment regarding professional racing bikes and mountainbikes for men and women.

In summer 2015, both CEOs, John Davis (USA) and Peter Schwarz (Germany) discussed current trends like digitization, Industry 4.0, and Internet of Things (IoT). They decided to extend their business and to become a bikesharing provider.

This transformation of their company implies that the bikes are equipped with sensors which measure and transmit data like geodata, tyre pressure, etc. as well as an online system for tracing the use of the bikes and the contracts with the customers. Customers should be enabled to rent bikes using a mobile app. The data which is generated by the sensors and the app has to be analyzed. Moreover, the Global Bike Group is interested in customer feedback from social networks.

All these plans will result in major changes in the business processes of the Global Bike Corporation - the digital transformation of the business. These curriculum provides an overview of what a digital transformation can mean for a company.

The "traditional" Global Bike Group

Information regarding the "traditional" Global Bike Group is available here: Intro GBI Story (pdf)

>>back to glossary<<

>>back to modules overview<<

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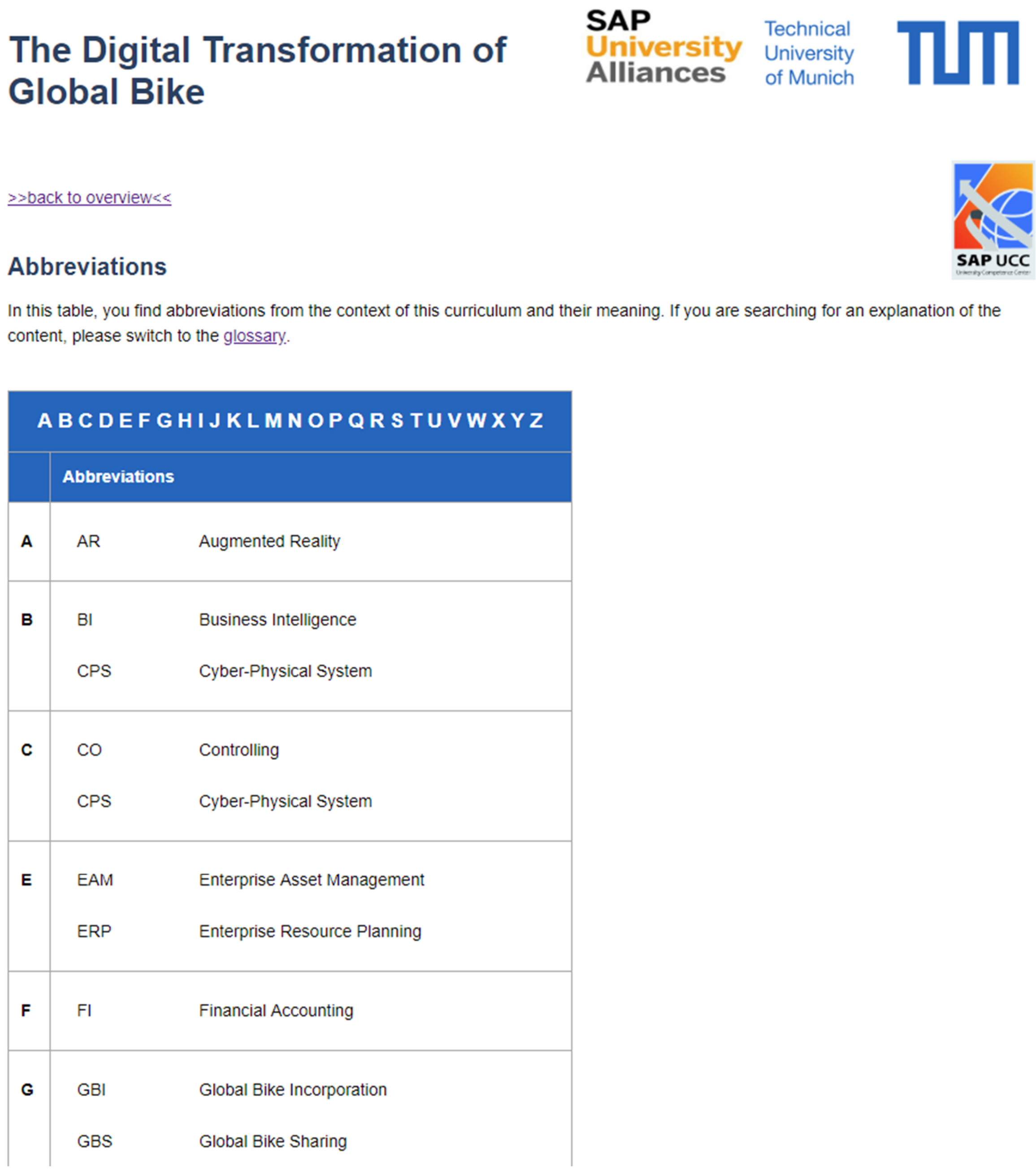
Figure 67: Glossary: Item (here: Global Bike) (screenshot from curriculum “The Digital Transformation of Global Bike”, provided by the SAP UCC Munich: Project Curriculum Development (2016 - 2017))

5.7.7 List of Abbreviations

Following the arguments for the implementation of the glossary (cp. section 5.7.7), we decided to add a second, quite simple aid for the users: a list of abbreviations. Very often, we read an abbreviation, of which the meaning usually is clear to us. Sometimes, we need a short reminder. The list of abbreviations included in the curriculum navigation application is shown in Figure 68.



The Digital Transformation of Global Bike

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>>back to overview<<

SAP UCC

Abbreviations

In this table, you find abbreviations from the context of this curriculum and their meaning. If you are searching for an explanation of the content, please switch to the glossary.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

	Abbreviations	
A	AR	Augmented Reality
B	BI	Business Intelligence
	CPS	Cyber-Physical System
C	CO	Controlling
	CPS	Cyber-Physical System
E	EAM	Enterprise Asset Management
	ERP	Enterprise Resource Planning
F	FI	Financial Accounting
G	GBI	Global Bike Incorporation
	GBS	Global Bike Sharing

Figure 68: List of Abbreviations: Landing Page (screenshot from curriculum "The Digital Transformation of Global Bike", provided by the SAP UCC Munich: Project Curriculum Development (2016 - 2017))

5.7.8 Evaluation of the Interactive and Supporting Elements and Materials

The pilot customers (cp. section 5.2.3) rated the discussion slides that are available in some of the slide decks with 3.9 points out of 5. However, in the pilot session, there were only few of those discussion slides contained. We would expect a slightly better rating on the first release of the curriculum "The Digital Transformation of GBI" – which contains more examples. However, there may be room for improving the discussion slides in a possible second release.

The participants of the “breakout sessions” (cp. section 5.2.2) rated the integration of interactive elements such as onlineTED and AnswerGarden at the example of onlineTED. The overall result of the evaluation in both “breakout sessions” was 4.3 points out of 5 – a positive result.

The Course Calculator was presented and rated in the “breakout sessions” as well. Some participants stated that they do not need such a tool at all, as everyone works on the same materials with different speed and intensity. They told us that they have a very good overview of how much materials they need for tailoring their individual teaching. Other lecturers face big difficulties in tailoring the curriculum for a whole term – they were very enthusiastic about the Course Calculator. In total, the course calculator was rated with 4.1 points out of 5 – a positive result.

The pilot customers (cp. section 5.2.3) rated the idea of the glossary with 4.3 points out of 5, and the list of abbreviations with 4.1 points out of four. Thus, these two items should be kept and extended in a possible second release.

5.8 Mechanisms for Evaluating Students’ Motivation and Opinions about Modules and Materials

Students’ or trainees’ motivation is an important aspect in learning (Keller, 2009). The students’ motivation affects their desire and motivation for learning and therefore has influence on their success in a lecture or training (Keller, 2009). Thus, the students’ feedback on a course or training given can support the lecturer in improving the learning environment in his sessions. To enable lecturers and trainers to evaluate their courses, we decided to offer them two surveys. These can be applied by lecturers or trainers to evaluate students’ or trainees’ opinions about lecturers or trainings. The surveys can be print and handed out – or conducted as online surveys, e.g., using LimeSurvey[74] or the survey functionality offered by Google. Keller (2009) developed, evaluated, and published two surveys for this purpose, building on the ARCS model, which measures Attention, Relevance, Confidence, Satisfaction. Table 66 gives an overview of the ARCS model.

Table 66: ARCS Model: Categories, Definitions, and Process Questions (with regards to Keller (2009))

Category	Definition	Process Question
Attention	Capturing the interest of learners; stimulating the curiosity to learn	How to make this learning experience stimulating and interesting?
Relevance	Meeting the personal needs/goals of the learner to effect a positive attitude	In what ways will this learning experience be valuable for the students?
Confidence	Helping the learners believe/ feel that they will succeed and control their success	How to instruct the students in order to help them succeed and allow them to control their success?

[74] LimeSurvey: Free, PHP-based online survey application, offered by LimeSurvey GmbH. https://www.limesurvey.org/. Accessed on August 26nd, 2018.

Category	Definition	Process Question
Satisfaction	Reinforcing accomplishment with rewards (internal and external)	What can be done in order to help the students feel good about their experience and desire to continue learning?

We stick to the ARCS approach as provided by Keller (2009) and offer the "Course Interest Survey" (CIS) for evaluating lectures or trainings (cp. section 5.8.1), as well as the "Instructional Materials Motivation Survey" (IMMS) for evaluating learning or training materials (cp. section 5.8.2). To check if these surveys are helpful for lecturers or instructors in the scope of our curriculum, we conducted pilot session with two lecturers and gathered their feedback on the usability and usefulness of the surveys in online structured expert interviews afterwards (cp. sections 5.8.1.2 and 5.8.2.2).

5.8.1 Questionnaire Regarding Students' Opinions about Modules: "Course Interest Survey" (CIS) as Proposed by Keller (2009)

For measuring the students' reaction to classroom instructions, we adjusted the questionnaire "Course Interest Survey" proposed by Keller (2009). Table 67 shows the introduction text that we recommend to show before our version of the CIS is started. The original introduction text as proposed by Keller (2009) can be found in Table 75 in appendix H.1.

5.8.1.1 The Adjusted Course Interest Survey for the Industry 4.0 Curriculum

Table 67: Introduction Text to the CIS (with regards to (Keller, 2009, p. 279))

Introduction Text
Dear XXX Module Participants/Students/Trainees, You have completed module XXX. We would like to improve the module, and your feedback is important to us. Therefore, we kindly request you to answer the questionnaire below. 1. There are 34 statements in this questionnaire. Please think about each statement in relation to the instructional materials you have just studied, and indicate how true it is. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear. 2. Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements. 3. Record your responses on the answer sheet that is provided, and follow any additional instructions that may be provided in regard to the answer sheet that is being used with this survey. 4. "1" means "disagree", "5" means "fully agree". Thank you for participating!

Similar to the introduction text, we slightly adjusted the survey questions proposed by Keller (2009) to better address our audiences. Main changes are slight adjustments to simplify the language, the replacement of the term “instructor” by “lecturer”, and the reference to the “subject matter” as “topic”. Table 68 shows the 34 questions of the adjusted CIS. A comparison between the original questions proposed by Keller (2009) is given in Table 76 in appendix H.1.

Table 68: Questionnaire: CIS (with regards to (Keller, 2009, p. 279 f.))

No.	Question (1 means disagree, 5 means fully agree) 1 – 5 scale, “No answer”
1	The lecturer knows how to make us feel enthusiastic about the topics in the course.
2	The theoretical and practical topics I am learning in this course will be useful to me.
3	I feel confident that I will do well in this course.
4	This class has very little in it that captures my attention.
5	The instructor makes the topics of this course seem important.
6	You have to be lucky to get good grades in this course.
7	I have to work too hard to succeed in this course.
8	I do NOT see how the content of this course relates to anything I already know.
9	Whether or not I succeed in this course is up to me.
10	The lecturer makes the course exciting.
11	The topics of this course are too difficult for me.
12	I feel that this course gives me a lot of satisfaction.
13	In this class, I try to achieve high standards of excellence.
14	I feel that the grades or other recognition I receive are fair compared to other students.
15	The students in this class seem curious about the subject matter.
16	I enjoy working for this course.
17	It is difficult to predict what grade the lecturer will give for my assignments.
18	I am pleased with the lecturer’s evaluation of my work compared to how well I think I have done.
19	I feel satisfied with what I am getting from this course.
20	The content of this course relates to my expectations and goals.
21	The lecturer does unusual or surprising things that are interesting.
22	The students actively participate in this class.
23	To accomplish my goals, it is important that I do well in this course.
24	The lecturer uses an interesting variety of teaching techniques.
25	I do NOT think I will benefit much from this course.
26	I often daydream while in this class.
27	As I am taking this class, I believe that I can succeed if I try hard enough.
28	The personal benefits of this course are clear to me.
29	My curiosity is often stimulated by the questions asked or the problems given in this class.
30	I find the challenge level in this course to be about right: neither too easy not too hard.
31	I feel rather disappointed with this course.
32	I feel that I get enough recognition of my work in this course by means of grades, comments, or other feedback.
33	The amount of work I have to do is appropriate for this type of course.
34	I get enough feedback to know how well I am doing.

The questionnaire is followed by statistical questions regarding the participant, his subject of study and his study progress. These questions are documented in appendix H.3.

The evaluation of the answers of the participants of the CIS is conducted using the scoring guide, which is shown in Table 69. It divides the questions into the four ARCS categories for measuring them separately. The minimum score of the survey is 34 (as it has 34 items), the maximum is 170, and the midpoint is 102. For the questions remarked as "reverse", the "reversed" values have to be calculated, i.e. 1 = 5, 2 = 4, 3 = 3, 4 = 2, 5 = 1.

Table 69: Scoring Guide for the CIS (with regards to Keller (2009))

Attention (min. 8, max. 40, midpoint 24)	**Relevance** (min. 9, max. 45, midpoint 27)	**Confidence** (min. 8, max. 40, midpoint 24)	**Satisfaction** (min. 9, max. 45, midpoint 27)
1	2	3	7 (reverse)
4 (reverse)	5	6 (reverse)	12
10	8 (reverse)	9	14
15	13	11 (reverse)	16
21	20	17 (reverse)	18
24	22	27	19
26 (reverse)	23	30	31 (reverse)
29	25 (reverse)	34	32
	28		33

5.8.1.2 Piloting and Evaluation of the Course Interest Survey for the Curriculum "The Digital Transformation of Global Bike"

We applied the adjusted CIS in winter term 2017/18 in two IS programming lectures at TUM, with included lecture parts and practical parts. The adjusted instruction text for piloting the CIS is documented in appendix H.4. For evaluating the CIS, we conducted structured expert interviews with two lecturers via email. They evaluated the CIS in two iterations: First without knowing the results of their courses, second after getting the results. In the first iteration, they did not know the results of the survey regarding their classes. They were asked to answer the following questions in an Excel sheet provided via email:

1. As a participant of your own course, how would you have rated it?
2. What average answer do you expect from your participants?
3. How useful do you rate this survey for evaluating your practical?
4. Which questions are not needed?
5. What is missing?

Question 1 and 2 are posed in order to be able to compare the results with the results from the participant. Lecturer A was answering five questions very negative – but expected the participants to rate those questions much better. On the other hand, he rated twelve questions very positive – but expected the participants to rate them worse. On a scale from 1 – 5, with 5 being the most positive answer, he rated the usefulness of the CIS with 4. From the point of view of lecturer A, questions 9, 13, 21, 26, and 29 are not helpful for his evaluation of the course. However, he suggests adding an additional question: “I improved my skills significantly during this course”.

In the second iteration of the evaluation, the results of the CIS conducted in their classes were presented to the lecturers. They were asked to answer the following questions in an Excel sheet provided via email:

1. Are you surprised by the results of the survey for your class?
2. What are the questions with the most surprising average answer for you?
3. What may be reasons for the differences between your own estimation and the average results from the survey?
4. How useful do you rate this survey for evaluating your practical?
5. In your opinion, which questions are the most important ones?

The results of the survey are calculated for each lecturer in Table 70. It contains three rows for each lecturer:

1. How the lecturer would have rated his course as participant
2. What rating he expects from his participants
3. The participants’ rating.

Table 70: Scoring Results CIS-Evaluation

Lecturer	Rating	Attention 8 – 24 – 40	Relevance 9 – 27 – 45	Confidence 8 – 24 – 40	Satisf. 9 – 27 – 45	Total 34 – 102 - 170
	1. Lecturer’s	28	42	35	41	**147**
A	2. Expected	26	38	26	35	**125**
	3. Participants	25	29	28.5	34	**116.5**
Difference		**-1**	**-9**	**+2.5**	**-1**	**-8.5**
	1. Lecturer’s	32	40	34	39	**145**
B	2. Expected	29	38	33	33[75]	**133**
	3. Participants	27.6	34.6	30.4	32.6	**125.2**
Difference		**-1.4**	**-1.4**	**-2.6**	**-0.4**	**-4.8**

The own rating of lecturer A is much more positive than what he is expecting from his students. The student’s rating is more negative than expected, especially in the area of Relevance (-9). However, lecturer A was not surprised by the results of the CIS in his class. He rated the CIS as very useful for his teaching as “it provides [him with] insights from the student[s’] perspective”. He now rated the questions 3, 6, 19, 32, and 34 as most valuable ones. Lecturer B’s own rating is slightly better than the ratings he expected from the participants in the areas of Attention, Relevance and Confidence. In the Area of Satisfaction, there is a significant difference (-

[75] One empty answer of lecturer B was rated with the intermediate value, “3”.

6). The expected rating is slightly above the real rating of the participants in the areas of Attention and Satisfaction. The difference is bigger for the areas of Relevance and Confidence.

Obviously, experienced lecturers are able to anticipate the judgment of their participants regarding their course interest. The CIS is a powerful means to collect and analyse the participants' opinions for the lecturer. Both lecturers rated it as very useful for their teaching.

5.8.2 Questionnaire Regarding Evaluating Students' Opinions about Materials: "Instructional Materials Motivation Survey"

For measuring the students' reaction to course materials and self-directed instructional materials, we adjusted the questionnaire "Instructional Materials Motivation Survey" proposed by Keller (2009). Table 71 shows the introduction text that we recommend to show before our version of the IMMS is started. The original introduction text as proposed by Keller (2009) can be found in Table 77 in appendix H.2.

5.8.2.1 The Adjusted Instructional Materials Motivation Survey for the Industry 4.0 Curriculum

Table 71: Introduction Text to the IMMS (with regards to (Keller, 2009, p. 283))

Introduction Text
Dear XXX Module Participants/Students/Trainees, You have completed module XXX. We would like to improve the module, and your feedback is important to us. Therefore, we kindly request you to answer the questionnaire below. 1. There are 36 statements in this questionnaire. Please think about each statement in relation to the instructional materials you have just studied, and indicate how true it is. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear. 2. Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements. 3. Record your responses on the answer sheet that is provided, and follow any additional instructions that may be provided in regard to the answer sheet that is being used with this survey. 4. "1" means "disagree", "5" means "fully agree". Thank you for participating!

Analogue to our approach with the CIS, we slightly adjusted the survey questions of the IMMS proposed by Keller (2009) to better address our audiences. Main changes comprise slight adjustments to ease the language, the replacement of the term "instructor" by "lecturer", the reference to "materials" as "slides" and/or "exercises", the adoption of experiences or associations with the topic to possible jobs, and the correction of two misspellings. Table 72 shows the 36 questions of the adjusted IMMS. A comparison between the original questions proposed by Keller (2009) is given in Table 78 in appendix H.2.

Table 72: Questionnaire: IMMS (with regards to (Keller, 2009, p. 283 f.))

No.	Question (“1” means “disagree”, “5” means “fully agree”) 1 – 5 scale, “No answer”
1	When I first looked at this session, I had the impression that it would be easy for me.
2	There was something interesting at the beginning of this lesson that got my attention.
3	This material was more difficult to understand that I would like for it to be.
4	After reading the introductory information, I felt confident that I knew what I was supposed to learn from this lesson.
5	Completing the exercises of this lesson gave me a satisfying feeling of accomplishment.
6	It is clear to me how the content of this material is related to things I already know.
7	Many of the slides had so much information that it was hard to pick out and remember the important points.
8	These materials are eye-catching.
9	There were stories, pictures, or examples that showed me how this material could be important for the job.
10	Completing this lesson successfully was important to me.
11	The quality of the writing helped to keep my attention.
12	This lesson is so abstract that it was hard to keep my attention on it.
13	As I worked on this lesson, I was confident that I could learn the content.
14	I enjoyed this lesson so much that I would like to know more about this topic.
15	The slides of this lesson look dry and unappealing.
16	The content of this material is relevant to my interests.
17	The way the information is arranged in the slides and exercises helped keep my attention.
18	There are explanations or examples of how to apply the knowledge in the job.
19	The exercises in this lesson were too difficult.
20	This lesson has things that stimulated my curiosity.
21	I really enjoyed studying this lesson.
22	The amount of repetition in this lesson caused me to get bored sometimes.
23	The content and style of writing in this lesson convey the impression that its content is worth knowing.
24	I learned some things that were surprising or unexpected.
25	After working on this lesson for a while, I was confident that I would be able to pass a test on it.
26	This lesson was not relevant to my needs because I already knew most of it.
27	The wording in the slides and exercises was understandable to me.
28	The variety of reading passages, exercises, illustrations, etc., helped keep my attention on the lesson.
29	The style of writing is boring.
30	I could relate the content of this lesson to things I have seen, done, or thought about in my own life.
31	There are so many words on each slide that it is irritating.
32	It felt good to successfully complete this lesson.
33	The content of this lesson will be useful to me.

No.	Question ("1" means "disagree", "5" means "fully agree") 1 – 5 scale, "No answer"
34	I could not really understand quite a bit of the material in this lesson.
35	The good organization of the content helped me to be confident that I would learn this material.
36	It was a pleasure to work on such a well-designed lesson.

The questionnaire is followed by statistical questions regarding the participant, his subject of study and his study progress. These questions are documented in appendix H.3.

The evaluation of the answers of the participants of the IMMS is conducted using the scoring guide, which is shown in Table 73. It divides the questions into the four ARCS categories for measuring them separately. The minimum score of the survey is 34 (as it has 34 items), the maximum is 170, and the midpoint is 102. For the questions remarked as "reverse", the "reversed" values have to be calculated, i.e. 1 = 5, 2 = 4, 3 = 3, 4 = 2, 5 = 1.

Table 73: Scoring Guide for Course Interest Survey (CIS) (with regards to Keller (2009))

Attention (min. 8, max. 40, midpoint 24)	**Relevance** (min. 9, max. 45, midpoint 27)	**Confidence** (min. 8, max. 40, midpoint 24)	**Satisfaction** (min. 9, max. 45, midpoint 27)
2	6	1	5
8	9	3	14
12	10	4	21
12 (reverse)	16	7	27
15 (reverse)	18	13	32
17	23	19 (reverse)	26
20	26 (reverse)	25	
22 (reverse)	30	34 (reverse)	
24	33	35	
28			
29 (reverse)			
31 (reverse)			

5.8.2.2 Piloting and Evaluation of the Instructional Materials Motivation Survey for the Curriculum "The Digital Transformation of Global Bike"

We applied the adjusted IMMS in winter term 2017/18 in two IS programming lectures at TUM, with included lecture parts and practical parts. The adjusted instruction text for piloting the IMMS is documented in appendix H.4. For evaluating the adjusted IMMS, we conducted structured expert interviews with the lecturers via email. They evaluated the IMMS in two iterations: First without knowing the results of their courses, second after getting the results. For the evaluation, we used the same questions as for the CIS (cp. section 5.8.1.2), with the only difference in question 4 of the second iteration: "How useful do you rate this survey for evaluating **the material of** your practical?".As with the evaluation of the CIS (cp. section 5.8.1.2), question 1 and 2 are posed in order to be able to compare the results with the results from the participant. The results of the survey are calculated for each lecturer in Table 70. It contains three rows for each lecturer:

1. How the lecturer would have rated his course as participant
2. What rating he expects from his participants
3. The participants' rating.

Table 74: Scoring Results IMMS-Evaluation

Lecturer	Rating	Attention 12 – 36 – 60	Relevance 9 – 27 – 45	Confidence 9 – 27 – 45	Satisf. 6 – 18 – 30	Total 36 – 108 - 180
	1. Lecturer's	37	33	39	30	**139**
A	2. Expected	31	30	38	25	**124**
	3. Participants	23.5	28	29.5	24	**105**
Difference		**-7.5**	**-2**	**-8.5**	**-1**	**-19**
	1. Lecturer's	31	36	37	26	**130**
B	2. Expected	30	33	32	22	**117**
	3. Participants	30.8	32.1	32	21.3	**116.1**
Difference		**+0.8**	**-1.9**	**±0**	**-0.7**	**-0.9**

The own rating of lecturer A is significantly more positive than what he is expecting from his students. The student's rating is even significantly more negative than expected, especially in the areas of Attention (-7.5) and Confidence (-8.5)). At least for the results of some questions (especially questions 1, 3, 14 and 23), lecturer A was "definitely surprised" by the results of the IMMS in his class. After the first iteration, he rated the IMMS as useful, after the second iteration as not very useful for his teaching. For lecturer A, questions 7, 17, 19 and 25 are the most important ones. He would neither remove any questions from the IMMS nor suggest adding new ones. Lecturer B's rating in the area of Attention is quite similar to those of his participants – and how he expected it to be. His rating in the areas of Relevance, Confidence, and Satisfaction is significantly higher than those of the participants. However, he almost exactly anticipated the average ratings of the participants in these areas.

Experienced lecturers are able to anticipate the judgment of their participants regarding their course interest. The IMMS is a means to collect and analyse the participants' opinions regarding teaching materials. However, both lecturers rated it as less useful for their teaching than the CIS. This may be because the CIS gives more feedback regarding the performance of the lecturer while the IMMS focusses on the materials – which was more important to these lecturers. However, for evaluating course materials, the IMMS is a powerful tool as well.

5.8.3 Lecturer Notes for the Course Interest Survey and the Instructional Materials Motivation Survey for the Curriculum "The Digital Transformation of Global Bike"

The CIS and the IMMS have a quite similar structure. The instructions for participants to take part in the surveys are about the same. Therefore, we only provide one document that supports lecturers in the use of the surveys in the scope of the curriculum "The Digital Transformation of Global Bike" (Knigge, Bas, Prifti, 2017). This provides lecturers with a motivation and an introduction for using the surveys and a short overview of the ARCS model. Furthermore, it contains the scoring tables for the two surveys that is needed to calculate and rate the results of the filled questionnaires about the four categories Attention, Relevance, Confidence, and Satisfaction. With this short and descriptive note, the lecturer is easily enabled to use the CIS and the IMMS in his classes and for his materials – as printout on paper, or as well in an online implemented survey. He can analyse the results and derive measures from them to improve his teaching – or for giving feedback to curriculum designers and developers.

5.9 Findings from Applying the Design Thinking Approach to Curriculum Development

In our curriculum development project, we stuck to the five-step Design Thinking approach presented by Kembel (2017a). In the following, our learnings from applying the Design Thinking approach are presented. They are summarized in ten recommendations for the development of – especially technical – curricula.

5.9.1 Empathy – Who are our Stakeholders and What do they Need?

The only thing that was clear in the beginning of our curriculum development project was that we wanted to implement a new curriculum for teaching Industry 4.0. To understand our main stakeholders' – trainers/lecturers and trainees/students – needs, wishes, and pain points, we conducted four focus group interviews as described in section 3.5. Thus, we were able to talk with several potential customers and collect their pain points with existing curricula and wishes towards a new curriculum (cp. section 5.1), before we started any further steps in our curriculum development project. The only thing that was fixed at this point was the idea of developing a new curriculum for teaching Industry 4.0 topics. → Recommendations 1 and 2.

Recommendation 1: Requirement Analysis First

It may be tempting to develop a curriculum based on an emerging technology just because this technology is available. However, it is important to conduct a requirement analysis by identifying the stakeholders, their needs and wishes before starting to develop specific ideas.

Recommendation 2: Involve Training Stakeholders from the Beginning

As they are the main stakeholders, start talking to the stakeholders at different stages of the development of a technical curriculum right from the beginning. It is important to understand how they are thinking, teaching, and learning, their pain points, and what is important to them.

One interesting point is that all projects members use the curricula provided by SAP UA and the SAP UCCs themselves in university teaching, so we all had some insights ourselves as well.

However, it was important to listen to other lecturers without having in mind our own thoughts and prejudices. → Recommendation 3.

Recommendation 3: Allow Training Stakeholders to Talk Freely about their Needs, Wishes, and Pain Points

To get to know the real needs and pain points of the stakeholders, it is very important to LISTEN to what they tell you. Trying to direct discussions in a specific direction is not helpful. However, examples can help the stakeholders to start telling you about their own experiences, needs, and pain points. Let them talk and LISTEN to them.

5.9.2 Define – How can we Address one (or more) of our Stakeholders' Needs?

In the Define phases, we analysed the results and insights from the focus group interviews. We developed personas and PoVs that represent typical characteristics and needs of the curriculum's stakeholders (cp. sections 5.1.1 and 5.1.2). By doing so, we discovered that our lecturers had different goals and needs, some of which were opposed. Thus, we decided to consider this and provide teaching materials for different topics and at different level of difficulty and detail in the new curriculum to address the needs of the different customers in different teaching situations and with different personalities. We came up with the idea of implementing a modularly built curriculum where the lecturer can choose which modules he wants to use and how to combine them. → Recommendations 4 and 5.

Recommendation 4: Derive Goals from Requirements

It is important to structure the information gathered from the stakeholders and other sources to define one or more clear goals that should be served by the curriculum in development.

Recommendation 5: Use Personas and PoV Statements for Easier Identifications with Stakeholders and Goals

Personas with names, personal details, and PoV statements for the main needs are helpful for a project team to identify and empathize with the stakeholders. This is a means to remember and focus on the goals and requirements defined.

However, we did not start right away with implementing an Industry 4.0 curriculum based on our customers' needs. We integrated knowledge from literature and the experiences in curriculum design from fourteen years in the SAP UCC; where our curriculum development project was located. We started to analyse the topic of Industry 4.0 (cp. section 2.2, 2.3, 2.4, and 2.5) by analysing existing literature. In the final consequence, this led us to the development of the first version of our competency model for Industry 4.0, as described in section 4.1.3. In parallel we dived in the topics of learning, teaching, and training (cp. section 2.7), and curriculum development (cp. section 2.8) to be able to build on existing knowledge in our project. → Recommendation 6.

Recommendation 6: Complete your Findings with Best Practices

While developing a technical curriculum, the requirements derived from the stakeholders' statements should always be in the focus. However, it is important not to disregard previous work and experiences made by others. Thus, for a 360-degree view, it is important to review literature on the topic at hand as well as on training or curriculum development – and to consider best practices.

5.9.3 Ideate – Develop a Range of Possible Solutions – and Go for One

We discussed several possible solutions as described in section 5.3.1 for the overall structure of the new curriculum. After discussing these ideas in the project team concerning our customers' needs, we decided to go on with one of these options. → Recommendation 7.

Recommendation 7: Brainstorm for a Large Number of Possible Solutions – Allow for Unexpected Thoughts and Errors

After the requirements are fixed, possible solutions must be discovered. With creative techniques such as brainstorming, it is possible to generate different ideas. If aspects such as costs or feasibility are NOT considered in this phase, the creativity of the project team increases and unexpected ideas may be generated. Mistakes should not be punished or criticized, as this might decrease the creativity of the project team. It may turn out that an unexpected thought later makes up the base for the final solution.

5.9.4 Prototyping and Testing – Gather Feedback from Stakeholders Early and Often

Different groups of customers tested several items of the curriculum in different phases. An overview is given in section 5.2. This approach allowed us to react early on customer feedback and made us more confident that our curriculum would meet the customers' needs in the end. Additionally, it provided us with new, unexpected ideas from time to time. → Recommendations 8, 9, and 10.

Recommendation 8: Decide on an Idea and Test it as Early as Possible

After the decision for one solution is made, start prototyping as early as possible to get user feedback as soon as possible.

Recommendation 9: Build Tangible, Easy to Use Prototypes

Cheap and easy-to-build prototypes, which concentrate on one variable of the curriculum help to transport an idea to the stakeholders and get their valuable feedback. This allows you to proceed – or drop the idea and start over again at low costs if the requirements of the trainers/lecturers and trainees/students are not met.

Recommendation 10: Test your Prototypes, do not Hesitate to Step Back, Improve in Fast Iterations

The stakeholders' feedback on the prototype is valuable and should be considered seriously. It may be needed to step back or start over again – but in the end, this will lead to a better solution. Do several iterations in the further process of the curriculum development to make sure that the stakeholders' requirements are fulfilled. This may include prototyping and testing – or running through several or all of the Design Thinking phases again for certain parts.

From the experiences from the curriculum development project "The Digital Transformation of Global Bike", the integration of the Design Thinking approach is suited to improve the development of – especially technical oriented – curricula. The strength of the Design Thinking approach is the emphasis of the stakeholders' needs and the high support of creativity. Personal contact and constant feedback can reveal new and unexpected insights and lead to new ideas. The recommendations presented above are derived from our curriculum development project. They may support other curriculum developers in applying (parts of) the Design Thinking approach in their development process.

5.10 Summary

In this chapter, we described the development of our prototype Industry 4.0 curriculum "The Digital Transformation of Global Bike". We built the curriculum on the comprehensive competency model for employees in Industry 4.0, which was developed in chapter 4. The curriculum addresses many of these competencies – from domain-specific, rather technical topics to general topics such as teamwork, which are supported through exercises. Release 1 of the curriculum "The Digital Transformation of Global Bike" was published in September 2017, in the scope of the 22nd SAP Academic Conference EMEA 2017. Enhancements and minor changes that resulted from the "breakout session" at the 22nd SAP Academic Conference EMEA 2017 were implemented and set live until the end of 2017. In the first half of 2018, around thirty customers were already actively using the curriculum. The curriculum can serve as subject to future research. Time will show if teachers and learners accept the idea of a curriculum with modules that they can combine as they wish. It will be interesting to evaluate if they make use of the learning journeys and the interactive elements in practice and – of course, if they think that the curriculum can help to prepare future employees for working in Industry 4.0.

Besides wishes and some smaller remarks, we gathered a lot of positive feedback from potential customers – for the released curriculum as well as at different points in time in different evaluations during the curriculum development process. The curriculum covers a wide range of Industry 4.0 topics and offers learning materials at different levels of difficulty and detail. The modular structure as well as topic-specific learning journeys describe different paths through the curriculum. Different teaching methods are applied, such as slide decks, hands-on exercises, case studies, and small knowledge assessments. Thus, the curriculum addresses different kinds of lecturers and students in the fields of Economics, Business Informatics/IS, Informatics/Computer Sciences, and Engineering. Furthermore, the curriculum contains additional materials such as lecturer notes or the Course Calculator, which support the lecturer in his preparation and teaching. The curriculum is part of the service offering of SAP UA and the SAP UCCs now.

However, there is room for improving the curriculum – e.g., in a second release. There are still some minor bugs that should be fixed, e.g., spelling mistakes or erroneous links in the Curriculum Navigation Application. Additional modules may be added, e.g.,

Section “Industry 4.0 and Internet of Things”:

- Module(s) on (further) new technologies: blockchain, cognitive computing, cognitive bots

Section “Enabling Technologies”:

- Module on “Application Development and Management”
  - How can business applications be developed, deployed, and maintained in a cloud environment/Industry 4.0 environment?
- Module on “Customizing”
  - Customizing of cloud environments
- Module on “data”: master data, mater data management, general concepts which are technology-independent, standards for data representations
- Module on processes: design-criteria for processes, structuring processes, standards for process representations, process modelling in SAP S/4HANA
- Module on the migration from SAP ERP to SAP S/4HANA

Section “Integrated Business Processes”.

- Module on HR topics
- Module on Warehouse Management
- Module on Project Management Systems
- Real-world scenarios

Section “Cross-Cutting Topics” – “Digital Security”:

- Deep dive on security in connection with cloud computing

Together with bugs and ideas for improvement that arose during the writing and finalizing of this thesis, the issues were collected in a list and handed over to the SAP UCC Munich, which is responsible for the maintenance and further development of the curriculum “The Digital Transformation of Global Bike”. Thus, they can serve as input for the development of a second release of the curriculum.

Existing modules may be extended with further additional or more detailed materials. The glossary could be enhanced. Another idea would be to provide online quizzes for each learning unit on the one hand and overall online quizzes for whole modules or learning journeys on the other hand to enable students and lecturers to measure the learning outcomes more exactly.

Furthermore, we applied the Design Thinking approach to the curriculum process in order to focus on the customers' needs and to enhance creativity in our project. We believe that this supported our good evaluation results, which mainly build on the impression that the potential customers feel addressed and understood by the structure and elements of our curriculum. Resulting, we added a module "Design Thinking" to the curriculum, where information and materials are given that enable lecturers to conduct a Design Thinking workshop in their classes. Furthermore, we derived ten guidelines for enhancing curriculum development with Design Thinking principles.

In total, release 1 of the prototype Industry 4.0 curriculum "The Digital Transformation of Global Bike" represents an artefact which is in use in practice now, which could be enhanced – and which may serve as subject to future research. The guidelines for applying Design Thinking in curriculum development may support future curriculum development projects.

6 Conclusion and Outlook

In this chapter, an overview of the results of this work is given. Limitations as well as topics for future research are listed. Implications for research and practice are outlined. In the end, we provide an overall résumé of this work.

6.1 Results and Outcomes

After presenting an overview of the topic of Industry 4.0, the historical development, related technologies and consequences, we developed a comprehensive competency model for employees in Industry 4.0. This comprises not only Industry 4.0-specific, but general competencies as well. It considers earlier research in the areas of Industry 4.0 and competency models and was evaluated and enhanced with findings from practice – derived from German online job offers.

From taking a closer look at our comprehensive competency model for employees in Industry 4.0, we can conclude that most of the competencies contained in the model are no “new” competencies – except domain knowledge regarding new technological developments. However, the combination, the weighting and the expectation of how much of these competencies an employee should fulfil to what degree are new. We can see a shift from technical experts to technical generalists with an overview of the business. However, we believe, that not every employee is suited for fulfilling or able to cope with such a complex job. Moreover, at least in Germany, there is a limited amount of working people, and industry has to deals with the human resources and their capabilities at hand. Therefore, it is crucial to provide adequate education to (future) employees. The future may show if this leads to different Industry 4.0 job profiles, which consider how people want to – and are able to – work.

Building on the previously developed comprehensive competency model for employees in Industry 4.0, we implemented the prototype Industry 4.0 curriculum “The Digital Transformation of Global Bike”. The first release of this curriculum is available in the context of SAP UA and the SAP UCCs since September 2017. It comprises materials for many Industry 4.0-related topics at different detail level and with focussing on different learning methods. Lecturers or instructors can use the modular structure of the curriculum or the comprised learning journeys to tailor their own lecture from the whole set of materials for different topics. Supporting materials such as lecturer notes or the Course Calculator help the lecturer in planning and conducting his lessons. Interactive features and small assessments help to attract and keep students’ attention and to measure the learning outcomes.

The curriculum can serve as subject to future research. Time will show if teachers and learners accept the idea of a curriculum with modules that they can combine as they wish. It will be interesting to evaluate if they make use of the learning journeys and the interactive elements in practice and – of course, if they think that the curriculum can help to prepare future employees for working in Industry 4.0.

During the curriculum development process, we applied the Design Thinking approach in order to focus on the customers' needs and to support creativity in the development project. This led to good results as we could gather a lot of positive feedback in different iterations of evaluation during the curriculum development project as well as for the first release. Therefore, we derived ten guidelines for applying Design Thinking in curriculum development to support future development projects for technology-related curricula.

6.1.1 Contributions to Theory

We provide a detailed and comprehensive overview of the historical development, the characteristics, dedicated technologies and possible consequences of Industry 4.0, which can serve as starting point for future research.

The evaluated, comprehensive competency model for employees in Industry 4.0 offers another entry point to future research. It may be enhanced with further domain-specific sections, used to analyse the situation on the job market, or used to derive qualification concepts or job profiles.

The prototype Industry 4.0 curriculum "The Digital Transformation of Global Bike" comprises several items that may serve as artefacts for further behavioural research. It will be interesting to evaluate the acceptance of the concept of the modules that can be combined, the learning journeys, and the interactive elements in practice.

The guidelines for applying the Design Thinking approach to the development of a technology-related curriculum may be subject to evaluation and refining.

6.1.2 Contributions to Praxis

The comprehensive competency model for employees in Industry 4.0 may support HR departments in deriving job profiles and job roles, in personnel planning or planning qualification and other topics. It may help education and training providers to tailor future teaching, training and qualification offerings. The competency model may also help companies to identify new topics and the corresponding need for new personnel as well as for new qualification measures.

The prototype Industry 4.0 curriculum "The Digital Transformation of Global Bike" is already offered to the customers of the SAP UCCs in the SAP UA context. In the first half of 2018, about thirty customers were already using it. Moreover, it may serve as example for tailoring further Industry 4.0-related qualification content.

Applying the Design Thinking approach to the development of technology-related curricula may help to focus on the users' needs and support creativity in the development projects – which may lead to better results.

6.2 Limitations of this work

As both, Industry 4.0 and the topics of Teaching, Education, and Qualification, are interdisciplinary; each of those touches several research areas. In the scope of this work, it was not possible to consider all Teaching, Education, and Qualification literature from all disciplines. We focussed on items that seemed to be relevant for our case and well recognized in science, e.g., by conducting the literature reviews on specific databases. It was not our goal to consider each psychological or neuroscientific aspect, but to build artefacts that now may be subject to further research in any of the fields connected to them – maybe with different focusses.

6.2.1 Job Offer Analysis

Our job offer analysis is restricted to German job offers. Due to technical changes at one of the platforms, the second, bigger data set mainly comprises job offers from only one platform. In the future, the job offer analysis could be extended to English and/or other languages and to more online platforms as well as to other online sources of job offers, e.g., to the career sections of company websites. However, as company websites have an individual structure that may differ a lot from each other, this will result in a higher effort. It has to be decided if the expected outcome would be worth it.

A second limitation of our job offer analysis is that we only reached an F_1-score of 81 % – while 90 % are a not uncommon value. We still face a high number of unrecognized competency requirements. Further improvements may be reached by extending the custom dictionaries and custom extraction rules, the transfer of the custom dictionaries into custom extraction rules, and the removal of html-tags from the texts ahead of the analysis.

6.2.2 Guidelines for Applying the Design Thinking approach to the Development of Technology-Related Curricula

We assume that the application of the Design Thinking approach to our curriculum development project had a big positive impact on our project by increasing the focus on the user and our creativity. However, we did not measure this impact. For future iterations of applying Design Thinking to curriculum development projects, a means for measuring the impact may be implemented.

6.3 Implications for Future Research/Work

From our research, we can derive implications for possible future research or work.

6.3.1 Implications for Future Research on Competencies for Employees in Industry 4.0

We identified several implications for future research regarding the analysis of competencies for employees in Industry 4.0.

6.3.1.1 Extension of the Data Basis of the Text Mining on Job Offers

Competency requirements may be collected from different sources from different countries over a longer period, e.g., 3 – 5 years. Thus, researchers would be enabled to examine changes that appear over time.

Including job offers from other, especially non-German sources, may lead to the discovery of more competencies – which may be more in the focus in other countries than in Germany. Such a data set would offer the opportunity to examine regional differences.

It may be an interesting approach to use clustering algorithms on the job offers in order to examine if patterns can be derived – which may be a sign for the emerge of new job profiles. E.g., in the last years, the data analyst has become a common job profile. There may be more new job profiles developing with Industry 4.0.

6.3.1.2 Comparison of the Competencies in the Competency Model for Employees in Industry 4.0 with the Actual Coverage of Qualifications of Employees

A next interesting step to sharpen the actual qualification needs could be to compare the competencies for employees in Industry 4.0 from the competency model presented with the qualifications employees today already have. In a first attempt, we used our TA application to analyse 1,067 curricula vitae (CVs) regarding the qualifications contained (Knigge, Willnecker, et al., 2020). Our idea was to compare those with the competencies in our model for employees in Industry 4.0 – and to examine, which fields of competencies are already well covered – and where there are gaps in qualification. However, we found out, that our TA would have to be significantly adjusted to extract qualifications of employees from CVs. CVs do not only contain the educational background of candidates. They contain information about the further work and participation in projects. Thus, it is needed to differentiate between project descriptions and the tasks that actually have been conducted by the candidates. This demands for an analysis not only of the text elements in a CV itself, but as well for considering the structure of a CV and the position where a competency is found. Therefore, the results of our first analysis are too imprecise to derive findings from them. As this was not in the focus of our work, we did not proceed with this approach so far.

6.3.1.3 Comparison of the Competencies in the Competency Model for Employees in Industry 4.0 with Education and Training Offerings

Another approach could be to compare the competency requirements against education and training offerings in order to discover gaps. New programmes for education and further education can be tailored based on the competency model.

6.3.1.4 Monitor the Development of Competency Requirements for Industry 4.0 over Time

It may be an interesting approach to collect larger amounts of online job offers from different sources and countries over a longer period, e.g., three to five years, to examine possible changes in competency requirements for employees in Industry 4.0 over time. From the results, implications for education and qualification might be derived. It may be possible to discover new trends very early with this approach.

6.3.2 Implications for Improving the Curriculum "The Digital Transformation of Global Bike"

There are two main aspects for further improving the curriculum "The Digital Transformation of Global Bike": Additional content and bug fixing and improvements. During the work on this thesis, issues and ideas have been collected and handed over to the SAP UCC Munich, which is in charge of maintaining the curriculum and a possible implementation of a second release.

6.3.2.1 Enhancement of the Content

Although the first version of the curriculum "The Digital Transformation of Global Bike" already covers a wide range of topics, there is demand for integrating further topics and modules. These may comprise:

Section "Industry 4.0 and Internet of Things":

- Module(s) on (further) new technologies: blockchain, cognitive computing, cognitive bots

Section "Enabling Technologies":

- Module on "Application Development and Management"
  - How can business applications be developed, deployed, and maintained in a cloud environment/Industry 4.0 environment?
- Module on "Customizing"
  - Customizing of cloud environments
- Module on "data": master data, mater data management, general concepts which are technology-independent, standards for data representations
- Module on processes: design-criteria for processes, structuring processes, standards for process representations, process modelling in SAP S/4HANA
- Module on the migration from SAP ERP to SAP S/4HANA

Section "Integrated Business Processes".

- Module on HR topics
- Module on Warehouse Management
- Module on Project Management Systems
- Real-world scenarios

Section "Cross-Cutting Topics" – "Digital Security":

- Deep dive on security in connection with cloud computing

The curriculum could be enhanced with a tool that allows customers to create and share their own learning journeys in a standardized design. A learning journey needs a topic and a description, a selection of the curriculum content, and – if available – links to further (external) materials on the topic. It may add value to the curriculum if customers can share their self-created learning journeys with others.

One important aspect when thinking about keeping the curriculum up-to-date is the speed of new technological developments. Curricula regarding ERP system have been valid for about fifteen years with only minor changes. The curriculum at hand faces new topics that emerge in much shorter periods, e.g., the topics mentioned above. On the other hand, parts of the content comprised in the curriculum may be outdated in shorter periods as well. Therefore, a strategy could be developed of how to identify and replace outdated content – and how and where to integrate new content. E.g., emerging technological topics that are extensive enough to fill an own module can easily be added in the modular structure in section 3 “Enabling Technologies”.

6.3.2.2 Approach: Object-Oriented Curriculum Building

One interesting approach to be able to generate or update curriculum content faster and with high quality could be to invent a kind of “Object-Oriented Curriculum Building”. This would mean to stop working with text documents and slides. Instead, a database could be set up which contains typical structural elements and text modules for each output type (e.g., texts, slides, videos, …). If new content is needed, these can be re-used easily. Changes could be made in one place and easily deployed to all relevant documents. This approach would enable a faster building or update of curricula – while increasing the quality through a high grade of standardization.

6.3.2.3 Further Evaluation of the Curriculum

It may be interesting to start another evaluation of the curriculum after customers gained more real-life experiences with it by using it for some terms in their classes. One means of evaluation could be to collect direct feedback via a questionnaire or focus group interviews. Another approach could be to examine the tickets customer opened at the SAP UCCs concerning this curriculum (indirect feedback). Moreover, it would be interesting to ask learners who worked with this curriculum how they rate it with regard to their jobs – and what they think is missing.

6.3.2.4 Bug Fixing and Improvements

During the different evaluation steps, bugs were identified (e.g., erroneous links in the Curriculum Navigation Application) and proposals for improvement were addressed to the curriculum development project team. Some reported bugs were not really bugs – but resulted from misunderstandings. Some proposals for improvement were already implemented in the meantime; others did not fit into the overall concept of the curriculum “The Digital Transformation of Global Bike”. Not all bugs were fixed and not all meaningful proposals for improvement were implemented before the release of version 1 of the curriculum “The Digital Transformation of Global Bike” due to time reasons.

6.4 Résumé

In conclusion, in the scope of this thesis a comprehensive and evaluated competency model for employees in Industry 4.0 was developed that builds on a wide range of different sources. It can serve as solid foundation for further research and has its relevance in practice as well, e.g, in the area of human resources.

The prototype Industry 4.0 curriculum "The Digital Transformation of Global Bike" is available in the scope of the SAP UA programme since September 2017. It is provided by the SAP UCCs to their worldwide customers. Several aspects of the curriculum were evaluated in different evaluation steps throughout the whole curriculum development process. The curriculum covers a wide range of Industry 4.0-related topics, presents them at different levels of detail and difficulty, and uses different learning methods. Impetus for enhancements that can be published in a second release is provided to the SAP UCC Munich, which maintains the curriculum.

Thus, the three research questions raised in the beginning of this thesis were answered comprehensively in this thesis.

Acknowledgements

I would like to thank Prof. Dr. Helmut Krcmar for giving me the opportunity to work at his chair including the opportunity to write this thesis. During my time at his chair, he gave me great support and personal motivation in working on this thesis. Besides, I enjoyed the opportunity of teaching students in several courses as part of my work. I am thankful for the valuable support of Dr. Sonja Hecht, who took care that I focussed on this work and who shared her experiences with me.

This thesis was written in the scope of the curriculum development project "The Digital Transformation of Global Bike" conjointly with the PhD thesis of Dr. Loina Prifti. I would like to thank her, Dr. Galina Baader and Dr. Alexander Löffler for working together, doing many reviews on papers and early fragments of this thesis, for lots of ideas, motivation, discussions, and coffee.

Furthermore, I would like to thank my colleagues Christopher Kohl, Dr. Kathrin Jasmin Kohl, Dr. Felix Willnecker, Nilüfer Deniz Bas, Maximilian Johannes Emanuel Barnert, Adrian Streitz, and Dr. Robert Zepic for their collaboration and their moral support. Moreover, I would like to thank Andrea Trost for her moral support and her special sense of humour.

I owe a great debt of gratitude to my parents, Wilma and Hermann Knigge, who encouraged and supported me while studying as well as while writing my PhD thesis. Special thanks go to Jorge Homann, Prof. Dr. Lutz Klimpel, Kerstin Prume, Mel, Isabell Füll, Nicole Heptner, Thomas Linke, and Arne Homann, who encouraged me to proceed with my work several times – and who gave me the room to relax and celebrate to gather new strength for my work on this thesis. Together with my sister Lisa D'Amore, her husband Giovanni, and their children and animals, they did a great job in moral support, especially when I had hard times because of being separated from family and friends during my stay at the TUM in Garching bei München. I want to thank Arjan Pater for supporting me and my work from the point we got to know each other and for building up a strong relationship with me although I was far away and working far too much during our first two years. And for Henk.

Finally yet importantly, I would like to thank my student assistants, Leon Kevin Birkel, Felix Maier, and Sai kiran Krishna murthy, who supported me when writing my PhD. Furthermore I would like to thank the students who did their theses or student projects under my advice and thus provided me with a lot of good discussions and ideas: Duygu Akdemir, Michael Bub, Sofia Christ, Dominik Figlestahler, Bastian Fischer, Isabel Fuhrmann, Frederic Furtmeier, Michael Gärtner, Alireza Ghazaei, Dennis Grimm, Sebastian Hagn, Seyedehmorvarid Khademhaghighat, Shoaib Khan, Taha Khan, Lukas Kick, Martin Kiener, Sebastian Kornprobst, Torben Korthals, Alexander Krämer, Borys Levkovskyi, Dominik Möslein, Hassan Najeeb, Andreea Niculescu, Andreas Obermeyer, Sebastian Pfaff, Marius Popp, Michael Riederer, Simon Schweiger, Laura Stojko, Tobias Sydekum, Aris Tsakpinis, Florian Veeser, Lisa Maria Walden, Marco Wenzel, Jiale Wang, Alexander Weinhardt, Raphael Wiegand, Yue Xie, and Xiuming Yan.

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Appendix A: Source Code for the Python Upload Script (python_upload_script.py)

```
import os
import pyhdb

### configuration ###
CONNECTION = pyhdb.connect(
    host="<replace with host of SAP HANA system>",
    port=<replace with port of SAP HANA system>,
    user="<replace with user>",
    password="<replace with password>"
)
TARGET_DIR = '<replace with directory'
SOURCE = TARGET_DIR[TARGET_DIR.rfind('_')+1:]
NEWTABLE = False
#####

if os.path.isdir(TARGET_DIR) is False:
    print('targetDir is not a valid directory. Exiting script')
    exit()

# new db session
CURSOR = CONNECTION.cursor()

if NEWTABLE:
    CURSOR.execute("DROP TABLE STELLENANZEIGEN")
    CURSOR.execute("CREATE COLUMN TABLE SYSTEM.STELLENANZEIGEN(id INT, filename  NVARCHAR(40),
filetype NVARCHAR(4), source  NVARCHAR(20), period DATE, content BLOB, duplicate BOOLEAN, PRIMARY
KEY(id))")
    # -> more info on LOB https://pypi.python.org/pypi/pyhdb/0.2.3#install
    max_id = 0
else:
    CURSOR.execute("SELECT MAX(ID) FROM STELLENANZEIGEN")
    max_id = CURSOR.fetchone()[0]
# print(max_id)

# uploading files
for dirpath, dirnames, filenames in os.walk(TARGET_DIR, topdown=True):
    del dirnames # no subdirectories will be looked into

    print(str(len(filenames)) + ' Dateien im Zielordner')

    i = max_id
    for file in filenames:
        i = i + 1
        file = open(os.path.join(TARGET_DIR, file), 'rb')
        content = file.read()
        CURSOR.execute("INSERT INTO SYSTEM.STELLENANZEIGEN(ID, FILENAME, FILETYPE, SOURCE, PE-
RIOD, CONTENT) VALUES(?,?,?,?,?,?)",
         (i,       os.path.basename(file.name),       os.path.basename(file.name)[os.path.base-
name(file.name).rfind('.')+1:],  SOURCE,  os.path.basename(dirpath)[:4]  +'-'+  os.path.base-
name(dirpath)[5:7] +'-01', content))
        file.close()
        print('ID ' + str(i) + ': ' + str(os.path.basename(file.name)) + ' ~' + str(round((i-
max_id)/len(filenames)*100, 1)) + '%')

# closing connection
CURSOR.close()
CONNECTION.commit()
CONNECTION.close()
```

Appendix B: Source Code Web Crawler for Job Offers from Online Job Portal

B.1 Web Crawler Administration

B.1.1 Crawler Start File (CrawlerAutorunAllPlatforms.bat)

```
cd C:\Program Files (x86)\hxe-jobutil\hxe-jobutil
node hxe-jobutil.js crawl "Industrie 4.0" --platform stepstone --limit 1000
cd C:\Program Files (x86)\hxe-jobutil\hxe-jobutil
node hxe-jobutil.js crawl "Industrie 4.0" --platform monster --limit 1000
exit
```

B.2 Web Crawler Files

B.2.1 Web Crawler (hxe-jobutil.js)

```
var config = require('config.js');
var fileSystemInvoker = require('invoker-fs.js');
var ConversionInvoker = require('invoker-conversion.js');
var JobCrawler = require('crawler.js');
var fs = require('fs');
var program = require('commander');
var winston = require('winston');
winston.level = config.loggingLevel;

var jobCrawler;
var directories = new Array();

var package = JSON.parse(fs.readFileSync('package.json'));

program
   .version(package.version)
   .description(package.description)
   .option('-b, --bypass', 'Bypass the staging database and directly create AnalysisData rec-
ords')
   .option('-s, --structured', 'Assume two layers of sub-folders representing search terms and
platforms')
   .option('-p, --platform <name>', 'The name of the job platform for crawling and parsing
purposes')
   .option('-l, --limit <integer>', 'Max number of job postings to request per crawling session')
   .option('-d, --date', 'Get results by date instead of relevance (crawl only)');

program
   .command('convert')
   .description('Parse all pending records in the staging table')
   .action(initiateParsing);

program
   .command('load <dir>')
   .description('Load HTML job postings from one ore more directories on disk')
   .action(initiateLoading);

program
   .command('crawl <searchTerm>')
   .description('Query a specified platform for job postings relevant to the search term')
   .action(initiateCrawling);

program
   .parse(process.argv);

if (program.args.length === 0) {
   program.help();
}
```

```
function initiateLoading(dir) {
   winston.info('Start loading job postings from disk...');
   if (program.structured) {
      winston.info('Assuming the presence of sub-folders');
   }

   if (fs.existsSync(dir)) {
      winston.debug('Directory exists: ' + dir);
   } else {
      winston.error(dir + ' does not exist');
      terminationHandler();
      return;
   }


   var invokerFunction = (program.bypass)
      ? fileSystemInvoker.loadIntoAnalysisTable
      : fileSystemInvoker.loadIntoStagingTable;
   var statusString = (program.bypass)
      ? 'Writing directly to AnalysisData table'
      : 'Writing to StagingData table. Subsequent call to convert required for analysis';

   if ((!program.structured) && (program.platform !== 'monster')) {
      winston.error('Single-file parsing is only supported for monster at this time');
      terminationHandler();
      return;
   }

   winston.info(statusString);
   invokerFunction(dir, program.structured, program.platform, terminationHandler.bind(this));
}

function initiateParsing() {
   winston.info('Start parsing unprocessed records from the staging table...');
   var conversionInvoker = new ConversionInvoker(terminationHandler.bind(this));
   conversionInvoker.parsePendingData();
}

function initiateCrawling(searchTerm) {
   var requestLimit = config.maxRequests;
   if ((program.platform !== 'monster') && (program.platform !== 'stepstone')) {
      winston.error('Crawling support is currently limited to monster and stepstone');
      terminationHandler();
      return;
   }
   winston.info('Querying ' + program.platform + ' for ' + searchTerm);
   if (program.limit && (program.limit <= config.maxRequests) && program.limit > 0) {
      winston.info('Set request limit to ' + program.limit);
      requestLimit = program.limit;
   } else {
      winston.warn('Defaulting to a request limit of ' + requestLimit);
   }

   var shouldSortByDate = (program.date) ? true : false;
   var sortingCriterionString = (shouldSortByDate) ? 'date' : 'relevance';
   winston.info('Ordering result list by ' + sortingCriterionString);

   jobCrawler = new JobCrawler(searchTerm, program.platform, requestLimit, shouldSortByDate,
terminationHandler);
   jobCrawler.crawl();
}

function terminationHandler(err, result) {
   if (err) {
      winston.error('Operation did NOT complete successfully.');
   }
   if (jobCrawler) {
      jobCrawler.tearDown();
   }

   winston.info('Execution terminated.');
}
```

B.2.2 Configuration File for Web Crawler (config.js)

```
var config = {
   // IP address for HANA server
   host : '<replace with host for SAP HANA server>',
   // port for HANA server
    port : <replace with port for SAP HANA server>,
    // user name for HANA server
    user : '<replace with user>',
    // password for user account
    password : '<replace with password>',
    // schema containing both tables
    schema : 'TEXTMINING',
    // Staging Data Table, e.g. STAGING_DATA_COMBINED4
    stagingTable : 'STAGING_DATA',
    // Staging Data Table, e.g. ANALYSIS_DATA_COMBINED5
    dataTable : 'ANALYSIS_DATA',
    // number of HANA connections to use while writing out queues
    // connections are pooled and are kept alive for a certain period
    maxParallelConnections : 1,
    // number of objects to be persisted
    // with one query (hdb bulk insert)
    chunkSize : 1,
    // number of records to be retrieved
    // with one query (hdb select)
    selectSize : 4,
    // language string for filtering
    // cf. languagedetect.getLanguages()
    postingLanguage : 'german',
    // Minimum number of key term (e.g. IoT) occurrences in a job title
    // If criterion is not met, the entire posting will be discarded
    requiredKeyTermsInTitle : 0,
    // Minimum number of key term occurrences in the posting
    // body for it to be considered relevant
    requiredKeyTermsInBody : 0,
    // list of search terms for loading from file system
    // first level of directory structure to be checked
    topics : ['Internet of Things', 'Industrie 4.0', 'Digitale Transformation'],
    // list of job platform names for loading from file system
    // second level of directory structure to be checked
   platforms : ['Stepstone', 'Monster'],
    // amount of information that will be logged to console
    // will be passed to the winston logging module
    // possible values: error, warn, info, verbose, debug, silly
    loggingLevel : 'debug',
    // maximum number of result list entries for the crawler
    // to consider. Be careful with this value so as to not
    // put undue stress on the platform's infrastructure
    maxRequests : 1000,
    // delay in seconds between two successive HTTP requests
    // to the platform during crawling
    crawlDelay : 10,//60
}

module.exports = config;
```

B.2.3 File System Invoker (invoker-fs.js)

```
var StagingData = require('staging-data.js');
var QueueConsumer = require('queue-consumer.js');
var DataConverter = require('data-converter.js');
var HanaClient = require('hana-client.js');
var fileSystemReader = require('fs-reader.js');
var path = require('path');
var _ = require('lodash');
var config = require('config.js');
var winston = require('winston');
winston.level = config.loggingLevel;


function loadIntoStagingTable(baseDirectory, structuredMode, platformName, eventualCallback) {
    load(baseDirectory, structuredMode, platformName, eventualCallback, persistQueue);
```

```
}

function loadIntoAnalysisTable(baseDirectory, structuredMode, platformName, eventualCallback) {
    load(baseDirectory, structuredMode, platformName, eventualCallback, convertToAnalysisData);
}

function load(baseDirectory, structuredMode, platformName, eventualCallback, intermediate-
Callback) {
    if (structuredMode) {
        fileSystemReader.importStructured(baseDirectory, intermediateCallback.bind(null, even-
tualCallback));
    } else {
        fileSystemReader.importSingle(baseDirectory, platformName, intermediate-
Callback.bind(null, eventualCallback));
    }
}

function convertToAnalysisData(eventualCallback, err, stagingQueue) {
    winston.info('Loading completed, starting conversion process...');
    var dataConverter = new DataConverter();

    // convert each StagingData object to AnalysisData
    // parsing occurs in this step
    var analysisQueue = _.map(stagingQueue, dataConverter.getValidAnalysisData.bind(dataCon-
verter));

    // remove invalid objects for which converter returned null
    _.remove(analysisQueue, function (currentElement) {
        return _.isNil(currentElement);
    });

    persistQueue(eventualCallback, null, analysisQueue);
}

function persistQueue(eventualCallback, err, result) {
    winston.info('Preparing to save data to HANA...');

    if (err) {
        eventualCallback(err);
        return;
    }
    if (!(_.isArray(result))) {
        eventualCallback(new Error('Nothing to persist'));
        return;
    }

    winston.info(result.length + ' eligible elements found');
    var hanaClient = new HanaClient();
    var queueConsumer = new QueueConsumer(result, hanaClient, finalize.bind(null, eventual-
Callback, hanaClient));
    queueConsumer.consume();
}

function finalize(eventualCallback, hanaClient) {
    winston.debug('invokerFs.finalize');
    hanaClient.tearDown(eventualCallback);
}

var interfaceDefinition = {
    loadIntoStagingTable: loadIntoStagingTable,
    loadIntoAnalysisTable: loadIntoAnalysisTable
};

module.exports = interfaceDefinition;
```

B.2.4 Conversion Invoker (invoker-conversion.js)

```
var StagingData = require('staging-data.js');
var AnalysisData = require('analysis-data.js');
var JobParserFactory = require('job-parser-factory.js');
var HanaClient = require('hana-client.js');
var DataConverter = require('data-converter.js');
var verifier = require('verifier.js');

var config = require('config.js');
```

```
var winston = require('winston');
winston.level = config.loggingLevel;


var ConversionInvoker = function(eventualCallback) {
   this.eventualCallback = eventualCallback;
   this.parsingQueue = new Array();
   this.parserManager = new JobParserFactory();
   this.hanaClient = new HanaClient();
    this.counter = 0;

   winston.debug('Created ConversionInvoker');
};

ConversionInvoker.prototype = {
    // function to be called from the outside
    parsePendingData : function () {
        winston.info('Fetch StagingData from database and parse...');
        // start by fetching raw data from database
        // max number of records: config.selectSize
        this.hanaClient.selectStagingData(this.handleSelectResults.bind(this));
    },
    // callback function handling the results of a select query
    // on the StagingData table for records which are as yet
    // unprocessed
    // produces StagingData objects and fills the parsing queue
    // with them
    handleSelectResults : function (err, resultArray) {
        if (err) {
            this.hanaClient.tearDown(this.eventualCallback);
            return;
        }

        winston.debug('Returned to invoker');
        var numRawData = resultArray.length;

        // if there are no (more) StagingData records awaiting processing,
        // we're done - hand back control
        if (numRawData === 0) {
            winston.info('No more StagingData to process, exiting...');
            this.hanaClient.tearDown(this.eventualCallback);
            return;
        } else {
            winston.debug('Obtained batch of ' + numRawData + ' records');
        }

        var context = this;
        resultArray.forEach(function (currentElement) {
            var generatedObject = new StagingData(currentElement);
            winston.debug('generatedObject: ' + generatedObject.getSummary());
            context.parsingQueue.push(generatedObject);
        })

        winston.debug('parsingQueue contains ' + this.parsingQueue.length + ' elements');

        this.consumeParsingQueue();
    },
    returnFromTransaction : function (statusString) {
        winston.debug('Returned from transaction.');
        if (statusString) {
            winston.info('Transaction was ' + statusString);
        }

        if (this.parsingQueue.length > 0) {
            // there are still elements in the current batch
            // awaiting processing
            this.consumeParsingQueue();
        } else {
            // fetch next batch of config.selectSize records
            this.hanaClient.selectStagingData(this.handleSelectResults.bind(this));
        }
    },
    // function to consume exactly one StagingData object from the parsing queue,
    // parse it, and initiate the database transaction to save the result
    consumeParsingQueue : function () {
```

```
        if (this.parsingQueue.length > 0) {
            this.counter++;
            var currentStagingObject = this.parsingQueue.shift();
            winston.debug('Preparing to insert ' + currentStagingObject.source
                + '::' + currentStagingObject.sourceId);
            var dataConverter = new DataConverter();
            var analysisObject = dataConverter.getValidAnalysisData(currentStagingObject);

            if (!analysisObject) {
                winston.debug('Object ignored (does not meet language and/or relevance crite-
ria)');
                this.hanaClient.updateStagingStatus(currentStagingObject,         this.return-
FromTransaction.bind(this));
                return;
            }

            this.hanaClient.insertAnalysisDataTx(analysisObject,       this.returnFromTransac-
tion.bind(this));
        } else {
            winston.info('No raw data pending transformation');
        }
    }
}


module.exports = ConversionInvoker;
```

B.2.5 Crawler (crawler.js)

```
var StagingData = require('staging-data.js');
var JobParserFactory = require('job-parser-factory.js');
var ListParserFactory = require('list-parser-factory.js');
var HanaClient = require('hana-client.js');
var QueueConsumer = require('queue-consumer.js');
var config = require('config.js');
var util = require('util.js');
var queueCleaner = require('queue-cleaner.js');
var request = require('request');
var fs = require('fs');
var path = require('path');
var async = require('async');
var _ = require('lodash');
var winston = require('winston');
winston.level = config.loggingLevel;

var headerOptions = {
   timeout: 8000,
   headers: {
      'User-Agent': 'curl/7.52.1',
      'Accept': '*/*',
      'Accept-Language': 'de'
   }
}

var JobCrawler = function (searchTerm, platformName, maxRequests, shouldSortByDate, eventual-
Callback) {
   this.searchTerm = searchTerm;
   this.platformName = platformName;
   this.maxRequests = maxRequests;
   this.shouldSortByDate = shouldSortByDate;
   this.eventualCallback = eventualCallback;
   this.taskQueue = new Array();
   this.stagingQueue = new Array();
   var parserManager = new JobParserFactory();
   this.jobParser = parserManager.getConcreteParser(this.platformName);
   var listParserManager = new ListParserFactory();
   this.listParser = listParserManager.getConcreteParser(this.platformName);
   this.hanaClient = new HanaClient();

   this.currentResultOffset = 0;
   this.numberOfResults = null;
   this.currentUrl = null;

   // set up output directory in file system
   var outputFolderRoot = path.join('.', 'crawler-fs');
```

```
   var outputFolderTopic = path.join(outputFolderRoot, searchTerm);
   this.outputFolder = path.join(outputFolderTopic, _.capitalize(platformName));
   if (!fs.existsSync(outputFolderRoot)) {
      fs.mkdirSync(outputFolderRoot);
   }
   if (!fs.existsSync(outputFolderTopic)) {
      fs.mkdirSync(outputFolderTopic);
   }
   if (!fs.existsSync(this.outputFolder)) {
      fs.mkdirSync(this.outputFolder);
   }

   winston.debug('Created JobCrawler with maxRequests=' + this.maxRequests);
};


JobCrawler.prototype = {
   crawl: function () {
      winston.debug('Invoked crawling method for ' + this.searchTerm + ' on ' + this.platform-
Name);
      var    firstPageUrl    =    this.listParser.generateInitialResultListUrl(this.searchTerm,
this.shouldSortByDate);
      this.currentUrl = firstPageUrl;
      winston.info('Sending request for: ' + firstPageUrl);
      request(firstPageUrl,     headerOptions,     this.requestCallback.bind(this,     this.lis-
tResultHandler.bind(this)));
   },
   requestCallback: function (handlerCallback, err, response, body) {
      winston.debug('Received request result');

      // if handlerCallback is set, request has been called in a custom control flow
      // else, it as been called from within an async structure and the callback is the
      // last argument.
      // also, async consumes the error, so we have to shift the remaining arguments
      var callback = handlerCallback;
      if (!handlerCallback) {
         callback = body;
         body = response;
         response = err;
      }

      if (err && handlerCallback) {
         winston.error(err.message);
         if (err.code === 'ETIMEDOUT') {
            if (err.connect) {
               // connect timeout
               winston.error('Timed out during connection attempt.');
            } else {
               // read timeout
               winston.error('Timed out while waiting for response.');
            }
         }
         // pass error info to callback and stop executing
         callback(err, null);
         return;
      }
      if (response.statusCode !== 200) {
         winston.error('Crawler received unexpected status code: ' + response.statusCode);
         var reqErr = new Error();
         reqErr.message = 'Could not handle response';
         callback(reqErr, null);
      } else {
         winston.info('Response OK');
         callback("", body);//null durch "" ersetzt
      }
   },
   listResultHandler: function (err, body) {
      winston.debug('JobCrawler.listResultHandler');
      if (err) {
         winston.error('Error while fetching next result list page: ' + err.message);
         this.handleError(err);
         return;
      }

      if ((this.currentResultOffset === 0) && (!this.numberOfResults)) {
```

```
      this.numberOfResults = this.listParser.getNumberOfResults(body);
      winston.debug('Total results for ' + this.searchTerm + ': ' + this.numberOfResults);
   }
   var candidateTasks = new Array();
   this.listParser.parseResultList(body, candidateTasks, this.searchTerm);

   // assume at least 25 results per page
   // in order to avoid requesting a result
   // page that does not exist
   this.currentResultOffset += Math.max(25, candidateTasks.length);

   winston.debug('Extracted ' + candidateTasks.length + ' results');
   winston.debug('Assumed offset: ' + this.currentResultOffset);

   // continue processing
   this.handleCandidateQueue(candidateTasks);
},
postingResultHandler: function (taskElement, body, callback) {
   winston.debug('JobCrawler.postingResultHandler');

   // write result to disk as a safety measure
   // sync call, do not continue until writing is done
   if(this.outputFolder==null)
   {
      winston.info('Attention!!!! This is an error mark! outputFolder=null!');
   }
   if(taskElement.sourceId==null)
   {
      taskElement.sourceId="";
      winston.info('Attention!!!! This is an error mark! taskElement.sourceId=null!');
   }
   var postingPath = path.join(this.outputFolder, taskElement.sourceId);
   if (!fs.existsSync(postingPath)) {
      fs.mkdirSync(postingPath);
   }
   var pageHtmlFile = path.join(postingPath, 'page.html');
   var urlFile = path.join(postingPath, 'url.txt');
   fs.writeFileSync(pageHtmlFile, body, 'utf8');
   fs.writeFileSync(urlFile, taskElement.pageUrl, 'utf8');

   var generatedStagingObject = new StagingData();
   generatedStagingObject.url = taskElement.pageUrl;
   generatedStagingObject.pageHtml = body;
   generatedStagingObject.source = this.platformName;
   generatedStagingObject.sourceId = taskElement.sourceId;
   generatedStagingObject.searchTerm = this.searchTerm;

   var iframeUrl = this.jobParser.extractIframeUrl(body, taskElement.pageUrl);
   if (iframeUrl) {
      winston.info('Iframe detected, starting request...');
      winston.info('Next request: ' + iframeUrl);
      async.series([
         this.startWithTimeout,
         this.wrapRequest.bind(this, iframeUrl, generatedStagingObject, callback)
      ])

   } else {
      winston.info('No iframe detected, returning...');
      callback(null, generatedStagingObject);
   }
},
iframeResultHandler: function (asyncCallback, stagingObject, err, body) {
   winston.debug('JobCrawler.iframeResultHandler');

   // propagate error to async.waterfall
   if (err) {
      asyncCallback(err, null);
      return;
   }

   // write result to disk as a safety measure
   // sync call, do not continue until writing is done
   var postingPath = path.join(this.outputFolder, stagingObject.sourceId);
   if (!fs.existsSync(postingPath)) {
      fs.mkdirSync(postingPath);
   }
```

```
      var frameHtmlFile = path.join(postingPath, 'iframe.html');
      fs.writeFileSync(frameHtmlFile, body, 'utf8');

      stagingObject.frameHtml = body;

      asyncCallback(null, stagingObject);
   },
   handleCandidateQueue: function (candidateQueue) {
      winston.debug('JobCrawler.handleCandidateQueue');
      // invoke cleaner
      queueCleaner.cleanQueue(this.taskQueue, candidateQueue, this.platformName, this.hanaCli-
ent, this.handleFilteredQueue.bind(this));
      //this.handleFilteredQueue(null, candidateQueue);
   },
   handleFilteredQueue: function (err, filteredQueue) {
      if (err) {
         winston.error('Filtering the list of URLs failed: ' + err.message);
         this.handleError(err);
         return;
      }
      winston.debug('JobCrawler.handleFilteredQueue');
      winston.debug(filteredQueue);

      // if we have more results than we should consider
      // according to our configuration, shorten the filtered queue
      if ((this.taskQueue.length + filteredQueue.length) > this.maxRequests) {
         var remainingElements = this.maxRequests - this.taskQueue.length;
         filteredQueue.splice(remainingElements);
      }

      this.taskQueue = _.union(this.taskQueue, filteredQueue);
      winston.info('Task queue now contains ' + this.taskQueue.length + ' elements');

      if  ((this.currentResultOffset  >=  this.maxRequests)  ||  (this.currentResultOffset  >=
this.numberOfResults)) {
         // trigger queue consumption
         //this.eventualCallback();

         //return;

         this.consumeTaskQueue();
      } else {
         // fetch next result list page
         var nextPageUrl = this.listParser.generateNextResultListUrl(this.currentUrl);
         winston.info('Next request: ' + nextPageUrl);
         this.currentUrl = nextPageUrl;
         this.startWithTimeout(request.bind(this, this.currentUrl, headerOptions, this.request-
Callback.bind(this, this.listResultHandler.bind(this))));
      }
   },
   consumeTaskQueue: function () {

      async.mapSeries(this.taskQueue,      this.executeTask.bind(this),      this.taskQueueFin-
ished.bind(this));
   },
   executeTask: function (taskElement, mapCallback) {
      winston.debug('async.execute ' + taskElement);
      winston.info('Next request: ' + taskElement.pageUrl);
      async.waterfall([
         this.startWithTimeout,
         request.bind(this, taskElement.pageUrl, headerOptions),
         this.requestCallback.bind(this, null),
         this.postingResultHandler.bind(this, taskElement)
      ], mapCallback);
   },
   startWithTimeout: function (callback) {
      winston.info('Waiting crawlDelay = ' + config.crawlDelay + ' seconds');
      setTimeout(callback, config.crawlDelay * 1000);
   },
   wrapRequest: function (iframeUrl, generatedStagingObject, originalCallback, seriesCallback)
{
      seriesCallback();
      request(iframeUrl,             headerOptions,             this.requestCallback.bind(this,
this.iframeResultHandler.bind(this, originalCallback, generatedStagingObject)));
   },
```

```
   taskQueueFinished: function (err, result) {
      winston.debug('JobCrawler.taskQueueFinished');
      this.stagingQueue = _.concat(this.stagingQueue, result);
      if (err) {
         winston.error(err.message);
         winston.error('Could not retrieve all queued job postings');
         winston.info('Intermediate results can be found in the crawler-fs directory');
         this.handleError(err, true);
         return;
      }

      winston.info('Finished retrieving the job postings');
      winston.debug('Staging queue: ' + this.stagingQueue);
      this.consumeStagingQueue();
   },
   consumeStagingQueue: function () {
      winston.debug('JobCrawler.consumeStagingQueue');
      if (this.stagingQueue.length === 0) {
         winston.warn('Nothing to persist. Exiting...');
         this.eventualCallback();
         return;
      }
      winston.info('Staging queue contains ' + this.stagingQueue.length + ' elements. Beginning
database operation...');
      var stagingConsumer = new QueueConsumer(this.stagingQueue, this.hanaClient, this.eventu-
alCallback);
      stagingConsumer.consume();
   },
   handleError: function (err, failedInTaskQueue) {
      if (failedInTaskQueue) {
         if (this.stagingQueue.length > 0) {
            // first, remove empty objects that may have been inserted
            _.remove(this.stagingQueue, function (currentElement) {
               return _.isNil(currentElement);
            });

            winston.info('Staging queue contains ' + this.stagingQueue.length + ' elements,
attempting to persist pending objects next...');
            this.consumeStagingQueue();
            return;
         } else {

            winston.info('Staging queue is empty, aborting...');
            this.eventualCallback(err);
            return;
         }
      } else {
         if (this.taskQueue.length > 0) {

            winston.info('Task queue is non-empty, attempting to execute pending tasks
next...');
            this.consumeTaskQueue();
            return;
         } else {

            winston.info('Task queue is empty, aborting...');
            this.eventualCallback(err);
            return;
         }
      }

   },
   tearDown: function () {
      winston.debug('JobCrawler.tearDown');
      this.hanaClient.tearDown();
   }
}

module.exports = JobCrawler;
```

B.2.6 Staging Data (staging-data.js)

```
/* Constructor takes optional argument that has to be an object as returned by HANA after a
** select query on the STAGING_DATA table */
var StagingData = function(optionalArg) {
```

```
   // auxiliary function to check whether the database
   // record has the required fields
   var isValidInput = function(candidateObject) {
      return (candidateObject.hasOwnProperty('ID')
         && candidateObject.hasOwnProperty('URL')
         && candidateObject.hasOwnProperty('SOURCE')
         && candidateObject.hasOwnProperty('SOURCE_ID')
         && candidateObject.hasOwnProperty('SEARCH_TERM')
         && candidateObject.hasOwnProperty('CREATION_DATE')
         && candidateObject.hasOwnProperty('PAGE_HTML')
         && candidateObject.hasOwnProperty('FRAME_HTML')
         && candidateObject.hasOwnProperty('IS_PROCESSED'));
   };

   if (optionalArg && isValidInput(optionalArg)) {
      this.id = optionalArg.ID;
      this.url = optionalArg.URL;
      this.source = optionalArg.SOURCE;
      this.sourceId = optionalArg.SOURCE_ID;
      this.searchTerm = optionalArg.SEARCH_TERM;
      this.creationDate = optionalArg.CREATION_DATE;
      this.pageHtml = (optionalArg.PAGE_HTML) ? optionalArg.PAGE_HTML.toString() : null;
      this.frameHtml = (optionalArg.FRAME_HTML) ? optionalArg.FRAME_HTML.toString() : null;
      this.isProcessed = optionalArg.IS_PROCESSED;
   } else {
      this.id = 0;
      this.url = null;
      this.source = null;
      this.sourceId = null;
      this.searchTerm = null;
      this.creationDate = null;
      this.pageHtml = null;
      this.frameHtml = null;
      this.isProcessed = false;
   }
};

StagingData.prototype = {
   getSummary : function() {
      return '``\tStaging data object #' + this.id + ' from ' + this.source
      + '\n\tURL: ' + this.url
      + '\n\tInternal ID: ' + this.sourceId
      + '\n\tPage HTML: ' + this.getPagePreview()
      + '\n\tFrame HTML: ' + this.getFramePreview();
   },
   // auxiliary function for getSummary
   getPagePreview : function() {
      if (this.pageHtml) {
         return this.pageHtml.slice(0,50) + '...';
      } else {
         return '*empty*';
      }
   },
   getFramePreview : function() {
      if (this.frameHtml) {
         return this.frameHtml.slice(0,50) + '...';
      } else {
         return '*empty*';
      }
   },
   // return values to be stored in database table,
   // to be passed to the database client for insertion
   toArray : function () {
      // do not include creation date to let HANA insert current date
      return [
         this.url,
         this.source,
         this.sourceId,
         this.searchTerm,
         this.pageHtml,
         this.frameHtml,
         this.isProcessed
      ];
   }
};
```

```
module.exports = StagingData;
```

B.2.7 Queue Consumer (queue-consumer.js)

```
var StagingData = require('staging-data.js');
var AnalysisData = require('analysis-data.js');
var HanaClient = require('hana-client.js');
var config = require('config.js');
var async = require ('async');
var _ = require('lodash');
var winston = require('winston');
winston.level = config.loggingLevel;


var QueueConsumer = function(inputQueue, hanaClient, eventualCallback) {
    this.objectQueue = inputQueue;
    this.eventualCallback = eventualCallback;
    this.hanaClient = hanaClient;

    this.typeString = null;
    this.insertionFunction = null;

   this.chunkSize = config.chunkSize;
   this.maxParallelConnections = config.maxParallelConnections;

    var isStagingData = true;
    var isAnalysisData = true;
   inputQueue.forEach(function (candidateObject) {
      isStagingData = (isStagingData && (candidateObject instanceof StagingData));
        isAnalysisData = (isAnalysisData && (candidateObject instanceof AnalysisData));
   })
   if (isStagingData || isAnalysisData) {
      this.typeString = (isStagingData)
            ? 'StagingData'
            : 'AnalysisData';
        this.insertionFunction = (isStagingData)
            ? this.hanaClient.insertStagingData.bind(this.hanaClient)
            : this.hanaClient.insertAnalysisData.bind(this.hanaClient);
        this.chunkSize = (isStagingData)
            ? Math.max(1, Math.round(this.chunkSize / 2))
            : this.chunkSize;
   } else {
        eventualCallback(new Error('Cannot persist queue contents due to unsupported type'));
        return;
    }



    this.partionedQueue = _.chunk(this.objectQueue, this.chunkSize);
    winston.debug('partitionedQueue: ' + this.partionedQueue);
    winston.debug('first chunk: ' + this.partionedQueue[0]);
    winston.debug('first element: ' + this.partionedQueue[0][0].getSummary());



   winston.debug('Created  QueueConsumer  for  '  +  this.typeString  +  '  with  chunkSize='  +
this.chunkSize);
};


QueueConsumer.prototype = {
   consume : function () {
      winston.debug('Invoked consumer method');

        async.eachLimit(this.partionedQueue,  this.maxParallelConnections,  this.insertionFunc-
tion, this.eventualCallback);
   }
}

module.exports = QueueConsumer;
```

B.2.8 Data Converter (data-converter.js)

```
var StagingData = require('staging-data.js');
var AnalysisData = require('analysis-data.js');
var JobParserFactory = require('job-parser-factory.js');
var verifier = require('verifier.js');
var config = require('config.js');
var _ = require('lodash');
var winston = require('winston');
winston.level = config.loggingLevel;


var DataConverter = function () {
    this.parserManager = new JobParserFactory();
    this.languageParameters = {
        defensiveMode: false,
        confidenceDiffThreshold: 0.01
    };

    winston.debug('Created DataConverter');
};


DataConverter.prototype = {
    getValidAnalysisData: function (stagingObject) {
        var isUsable = (!(_.isEmpty(stagingObject)) && (stagingObject instanceof StagingData)
&& stagingObject.source);
        if (!isUsable) {
            return null;
        }
        var jobParser = this.parserManager.getConcreteParser(stagingObject.source);
        if (!jobParser) {
            return null;
        }

        // at this point, stagingObject is valid and its source property
        // contained a platform name that we can handle
        var analysisObject = jobParser.parse(stagingObject);

        if     (!verifier.isInLanguage(analysisObject.postingBody,     config.postingLanguage,
this.languageParameters)) {
            return null;
        }
        if (!verifier.postingBodyIsRelevant(analysisObject.postingBody)) {
            return null;
        }

        // at this point, analysisObject satisfies our constraints and
        // can be returned
        winston.info('Successfully  parsed  item  with  title  "'  +  analysisObject.getShort-
enedTitle() + '"');
        return analysisObject;
    }
}

module.exports = DataConverter;
```

B.2.9 SAP HANA Client (hana-client.js)

```
var async = require ('async');
var hdb = require('hdb');
var Pool = require('generic-pool').Pool;
var config = require('config.js');
var AnalysisData = require('analysis-data.js');
var StagingData = require('staging-data.js');
var winston = require('winston');
winston.level = config.loggingLevel;

function HanaClient() {
   this.pool = new Pool({
      name : 'hdb-client-pool',
      create : function(callback) {
```

```
         // create new HANA client instance
         var client = hdb.createClient({
            host : config.host,
            port : config.port,
            user : config.user,
            password : config.password
         });
         // register event listeners for logging purposes
         client.on('connect', function () {
            winston.info('HANA Client: connected to ' + config.host + ':' + config.port);
         });
         client.on('disconnect', function () {
            winston.info('HANA Client: disconnected from ' + config.host + ':' + config.port);
         });
         client.on('close', function () {
            winston.info('HANA Client: closed');
         });
         client.on('error', function (err) {
            winston.error('HANA Client encountered an error: ', err);
         });

         // initiate connection
         client.connect(function (err) {
            if (err) {
               callback(err);
            } else {
               callback(null, client);
            }
         });
      },
      destroy : function(client) {
         // ensure orderly disconnection before client instance is evicted
         client.end();
      },
      // only return clients that are ready to be used
      // otherwise, the instance will be destroyed
      validate : function(client) {
         return (client.readyState === 'connected');
      },
      max : 2,
      // destroy unused clients after 5 seconds
      // Pool will also remain in event queue during this period and
      // prevent the program from exiting unless immediate destruction
      // of all clients is triggered through HanaClient.tearDown
      idleTimeoutMillis : 5000,
      // lazily re-instantiate timed-out clients
      refreshIdle : false,
      // allow verbose output from the pool module only if
      // such behavior is desired from the program as a whole
      log : (config.loggingLevel === 'debug' || config.loggingLevel === 'silly')
   });
}

HanaClient.prototype = {
   // to be called from invoker
   // accepts array of AnalysisData objects
   // creates array of array which can be used for insert query
   // obtains HANA client and hands off control
   insertAnalysisData : function (objectArray, cbFin) {
      // check type of array elements
      var typeOk = true;
      objectArray.forEach(function (candidateObject) {
         typeOk = (typeOk && (candidateObject instanceof AnalysisData));
      })
      if (!typeOk) {
         return null;
      }
      var arrayArray = this.createInsertionArray(objectArray);
      if (!arrayArray) {
         // if conversion of the input data fails, skip any database operations
         this.terminate(null,  cbFin,  new  Error('Invalid  input  data,  persistence  operation
failed'));
      }
      // input data checks out, try to obtain database client next
      if (objectArray && objectArray.length == 1) {
```

```
        winston.info('Saving to database: ' + objectArray[0].source + '/' + objectAr-
ray[0].sourceId);
      }
      this.acquireClientAndContinue(this.insertAnalysisDataAsync, [arrayArray, cbFin]);
   },
   // internal method, not to be called from the outside
   // defines control flow and curries sub-methods with
   // parameters from invoker
   insertAnalysisDataAsync : function(client, arrayArray, cbFin) {
      async.waterfall([
         this.prepareAnalysisDataInsert.bind(this, client),
         this.executeStatement.bind(this, arrayArray),
         this.printResults.bind(this)
      ], this.terminateInsert.bind(this, client, cbFin));
   },
   // to be called if analysisDataObject failed verification criteria
   // sets isProcessed to true without moving data to analysis table
   updateStagingStatus : function (stagingDataObject, cbFin) {
      // check type of argument
      if (!(stagingDataObject instanceof StagingData)) {
         cbFin(new Error('Invalid input where StagingData was expected'));
         return;
      };
      var recordId = [ [ stagingDataObject.id ] ];
      // input data checks out, try to obtain database client next
      this.acquireClientAndContinue(this.updateStagingStatusAsync, [recordId, cbFin]);
   },
   // internal method, not to be called from the outside
   // defines control flow for updating the corresponding STAGING_DATA record
   updateStagingStatusAsync : function(client, recordId, cbFin) {
      async.waterfall([
         this.prepareStagingStatusUpdate.bind(this, client),
         this.executeStatement.bind(this, recordId),
         this.printResults.bind(this)
      ], this.terminateInsert.bind(this, client, cbFin));
   },
   // to be called from invoker
   // accepts a single AnalysisData object which it persists in a transaction
   // obtains HANA client and hands off control
   insertAnalysisDataTx : function (analysisDataObject, cbFin) {
      // check type of argument
      if (!(analysisDataObject instanceof AnalysisData)) {
         cbFin(new Error('Invalid input where AnalysisData was expected'));
         return;
      };
      var recordId = [ [ analysisDataObject.id ] ];
      var arrayArray = [ analysisDataObject.toArray() ];
      if (!arrayArray) {
         // if conversion of the input data fails, skip any database operations
         this.terminateInsert(null, cbFin, new Error('Invalid input data, persistence operation
failed'));
      }
      // input data checks out, try to obtain database client next
      winston.info('Saving to database: ' + analysisDataObject.source + '/' + analysisDataOb-
ject.sourceId);
      this.acquireClientAndContinue(this.insertAnalysisDataAsyncTx, [arrayArray, recordId,
cbFin]);
   },
   // internal method, not to be called from the outside
   // defines control flow for the transaction of saving an AnalysisData object
   // and updating the corresponding STAGING_DATA record
   insertAnalysisDataAsyncTx : function(client, arrayArray, recordId, cbFin) {
      winston.debug('Starting tx for id=' + recordId);
      client.setAutoCommit(false);
      async.waterfall([
         this.prepareAnalysisDataInsert.bind(this, client),
         this.executeStatement.bind(this, arrayArray),
         this.printResults.bind(this),
         this.prepareStagingStatusUpdate.bind(this, client),
         this.executeStatement.bind(this, recordId),
         this.printResults.bind(this)
      ], this.terminateTransaction.bind(this, client, cbFin));
   },
   // to be called from invoker
   // obtains HANA client and launches query
```

```
   selectStagingData : function (cbFin) {
      this.acquireClientAndContinue(this.selectStagingDataAsync, [cbFin]);
   },
   selectStagingDataAsync : function(client, cbFin) {
      async.waterfall([
         this.queryStagingData.bind(this, client)
      ], this.terminateQuery.bind(this, client, cbFin));
   },
   // checks which, if any, of a given set of IDs have
   // corresponding records in the analysis table
   selectSourceIds : function (platform, idArray, cbFin) {
      // perform basic input cleansing to avoid SQL injection
      var sanitizingRegex = /[.;'"%&]/g; //+ vor /g entfernt
      var idString = '(';
      if (idArray && (idArray.length > 0)) {
         var firstElement;
         if (idArray[0]!= null){ // If Statement eingefügt da es sonst zu Fehlern kommt
            firstElement = String(idArray[0].replace(sanitizingRegex, ''));
         }
          idString += ("'" + firstElement + "'");
          for (var i=1; i < idArray.length; i++) {
              idString += ',';
              var currentElement = String(idArray[i]);
              var cleanElement = currentElement.replace(sanitizingRegex, '');
              idString += ("'" + cleanElement + "'");
           }
      }
      idString += ')';
      this.acquireClientAndContinue(this.selectSourceIdsAsync, [platform, idString, cbFin]);
   },
   selectSourceIdsAsync : function(client, platform, idString, cbFin) {
      async.waterfall([
         this.querySourceIds.bind(this, client, platform, idString)
      ], this.terminateQuery.bind(this, client, cbFin));
   },
   // analogous to insertAnalysisData
   // entry point for file system and web data emitters
   insertStagingData : function (objectArray, cbFin) {
      // check type of array elements
      var typeOk = true;
      objectArray.forEach(function (candidateObject) {
         typeOk = (typeOk && (candidateObject instanceof StagingData));
      })
      if (!typeOk) {
         return null;
      }
      var arrayArray = this.createInsertionArray(objectArray);
      if (!arrayArray) {
         // if conversion of the input data fails, skip any database operations
         this.terminate(null,  cbFin,  new  Error('Invalid  input  data,  persistence  operation
failed'));
      }
      // input data checks out, try to obtain database client next
      if (objectArray && objectArray.length == 1) {
         winston.info('Saving  to  database:  '  +  objectArray[0].source  +  '/'  +  objectAr-
ray[0].sourceId);
      }
      this.acquireClientAndContinue(this.insertStagingDataAsync, [arrayArray, cbFin]);
   },
   // analogous to insertAnalysisDataAsync
   insertStagingDataAsync : function(client, arrayArray, cbFin) {
      async.waterfall([
         this.prepareStagingDataInsert.bind(this, client),
         this.executeStatement.bind(this, arrayArray),
         this.printResults.bind(this)
      ], this.terminateInsert.bind(this, client, cbFin));
   },
   // bulk insert into ANALYSIS_DATA
   prepareAnalysisDataInsert : function (client, callback) {
      winston.debug('-- prepare AnalysisData');
      var sql = 'insert into "' + config.schema + '"."' + config.dataTable
         +  '"  (SOURCE,SOURCEID,SEARCH_TERM,JOB_TITLE,JOB_LOCATION,JOB_TYPE,JOB_HOURS,JOB_COM-
PANY,POSTING_BODY,MIME_COLUMN) values(?,?,?,?,?,?,?,?,?,?)';
      winston.debug('---- query: ' + sql);
      client.prepare(sql, callback);
   },
```

```
   // update STAGING_DATA record to reflect new processed state
   prepareStagingStatusUpdate : function (client, callback) {
      winston.debug('-- prepare StagingStatusUpdate');
      var sql = 'update "' + config.schema + '"."' + config.stagingTable
         + '" set IS_PROCESSED=true WHERE ID=?';
      winston.debug('---- query: ' + sql);
      client.prepare(sql, callback);
   },
   // bulk insert into STAGING_DATA
   // Anker max1
   prepareStagingDataInsert : function (client, callback) {
      winston.debug('-- prepare StagingData');
      var sql = 'insert into "' + config.schema + '"."' + config.stagingTable
         +   '"    (URL,SOURCE,SOURCE_ID,SEARCH_TERM,PAGE_HTML,FRAME_HTML,IS_PROCESSED)    val-
ues(?,?,?,?,?,?,?)';
       winston.debug(sql);
      client.prepare(sql, callback);
   },
   // outputs rows returned by the database
   // also handles varying number of arguments depending on program state
   printResults : function(firstArg, callback) {
      winston.debug('Query executed.');
      if (typeof firstArg === 'function') {
         // nothing to display, first argument is in fact the callback function
         // this branch is reached in case of a duplicate record
         callback = firstArg;
      } else {
         // first argument contains results as returned by HANA
         winston.debug('### Rows affected ###\n', firstArg);
      }
       callback();
   },
   // callback function to be invoked by async.waterfall
   // once all regular functions have completed
   // used after bulk insert of both ANALYSIS_DATA and
   // STAGING_DATA
   terminateInsert : function(client, eventualCallback, err) {
       if (err) {
         this.handleError(err, client);
       }
       this.pool.release(client);
       if (eventualCallback) {
         eventualCallback();
      } else {
         this.tearDown();
      }
   },
   // final callback function to be invoked by async.waterfall
   // contains transaction commit and rollback handling
   terminateTransaction : function(client, eventualCallback, err) {
      winston.debug('-- terminateTransaction');
      var message;
      var context = this;
      if (!eventualCallback) {
         this.tearDown();
      }
      if (err) {
         // error within transaction
         winston.debug('-- error in tx');
         context.handleError(err, null);
         client.rollback(function (errRollback) {
            if (errRollback) {
               context.handleError(errRollback, client);
               message = 'aborted after rollback failure';
            } else {
               message = 'rolled back';
               client.end();
            }
            context.pool.release(client);
            eventualCallback(message);
         });
      } else {
         // queries were successful, ready to commit
         winston.debug('-- tx ok');
         client.commit(function (errCommit) {
```

```
            if (errCommit) {
               context.handleError(errCommit, client);
               message = 'aborted after commit failure';
            } else {
               message = 'sucessfully committed';
               // client has not been closed, therefore
               // reset client to default value before returning to pool
               client.setAutoCommit(true);
            }
            context.pool.release(client);
            eventualCallback(message);
         })
      }
   },
   // final callback in waterfall controlling the the retrieval of STAGING_DATA
   // records which have not yet been processed and IDs from the analysis table
   // cleans up resources and passes results to invoker
   terminateQuery : function (client, eventualCallback, err, results) {
      winston.debug('HanaClient.terminateQuery');
      if (err) {
         this.handleError(err, client);
         eventualCallback(err, null);
      }
      winston.debug('-- results');
      this.pool.release(client);
      if (eventualCallback) {
         eventualCallback(null, results);
      } else {
         this.tearDown();
      }
   },
   // generic method to execute statement with values in a two-dimensional array
   // modifies async control flow by redirecting the callback
   executeStatement : function (arrayArray, statement, callback) {
      winston.debug('HanaClient.executeStatement');
      // call filter function for error 301 instead of async callback
      // curry function to ensure callback argument is in the right place
      var interceptor = this.interceptCallback.bind(this, callback);
       statement.exec(arrayArray, interceptor);
   },
   // selects STAGING_DATA records which have not been parsed and converted into
   // ANALYSIS_DATA
   queryStagingData : function (client, callback) {
      winston.debug('HanaClient.queryStagingData');
      client.exec('select * from "' + config.schema + '"."' + config.stagingTable + '" where
IS_PROCESSED=false LIMIT ' + config.selectSize, callback);
   },
   // selects IDs for analysis data records which match one of the given IDs
   querySourceIds : function (client, platform, idString, callback) {
      winston.debug('HanaClient.querySourceIds');
      /*var queryString = 'select SOURCEID from "' + config.schema + '"."' + config.dataTable
         + '" where SOURCE=\'' + platform
         + '\' and SOURCEID in ' + idString;*/
      var queryString = 'select SOURCEID from "' + config.schema + '"."' + config.dataTable
         + '" ad where (ad.SOURCE=\'' + platform +'\' and ad.SOURCEID in ' + idString
         + ') UNION select SOURCE_ID as SOURCEID from "' + config.schema + '"."' + config.stag-
ingTable
         + '" sd where (sd.SOURCE=\'' + platform +'\' and sd.SOURCE_ID in ' + idString + ')';
      winston.debug(queryString);
      client.exec(queryString, callback);
   },
   // auxiliary function for acquiring hdb client instance from the pool
   // accepts a function and its parameters
   acquireClientAndContinue : function (callback, parameterArray) {
      winston.debug('HanaClient.acquireClientAndContinue');
      var context = this;
      this.pool.acquire(function(err, clientInstance) {
         if (err) {
            console.error('An error occurred while acquiring a HANA client from the pool: ' +
err);
         } else {
            // add database client to the front of the array, since all eligible
            // callback functions expect it as their first argument
            parameterArray.unshift(clientInstance);
            callback.apply(context, parameterArray);
         }
```

```
    });
  },
  // auxiliary function to convert array of AnalysisData or
  // StagingData objects to array of arrays with the same values,
  // so the latter can be passed to statement.exec
  createInsertionArray : function(objectArray) {
    winston.debug('HanaClient.createInsertionArray');
    // create new array of arrays
    var candidateArray = objectArray.map(function (dataObject) {
      // all objects passed to this method must implement a toArray
      // method that returns an array representation of their values
      return dataObject.toArray();
    })
    return candidateArray;
  },
  // auxiliary function to encapsulate repetitive task of checking error object
  // and closing the client with erroneous state if need be
  handleError : function (err, client) {
    winston.debug('HanaClient.handleError');
    if (err.code === 301) {
      // unique constraint violated, continue as normal
      winston.warn('Duplicate data was not written.');
    } else {
      winston.warn('An error occurred: ', err);
      winston.warn(err.stack);
      // close client with erroneous state
      // will not be dispensed by pool again
      if (client) {
        winston.info('Closing database client...')
        client.close();
      }
    }
  },
  // auxiliary function to be called within an async.js control flow
  // instead of the callback
  // expects async.js callback function as the first argument, which it will
  // eventually call in accordance with the contract, after having removed
  // any errors with code 301
  // this prevents a unique constraint violation from triggering a transaction
  // rollback
  interceptCallback : function () {
    var numberOfArguments = arguments.length;
    winston.debug('HanaClient.interceptCallback with ' + numberOfArguments + ' arguments');

    if ((numberOfArguments > 0) && (typeof arguments[0] == 'function')) {
      var callback = arguments[0];
      var argumentArray = new Array();
      // transform array-like argument object into array
      for (var i = 1; i < numberOfArguments; i++) {
        argumentArray.push(arguments[i]);
      }
      if ((numberOfArguments > 1) && (argumentArray[0])) {
        winston.debug('error filter');
        var err = argumentArray[0];
        if (err.code === 301) {
          // unique constraint violation is inherent in our database design and
          // therefore not considered an error
          // output warning and delete error object
          winston.warn('Unique constraint violated. Duplicate data was not written');
          argumentArray[0] = null;
        }
      }
      callback.apply(null, argumentArray);
    } else {
      // callback function was not in its expected place
      winston.debug('No callback function found, exiting...');
      return;
    }
  },
  // destroy all remaining instances in pool to avoid
  // delaying program termination by pool.idleTimeoutMillis
  tearDown : function(callback) {
    var poolInstance = this.pool;
    poolInstance.drain(function () {
      poolInstance.destroyAllNow(callback);
```

```
        });
    }
}

module.exports = HanaClient;
```

B.2.10 File System Reader (fs-reader.js)

```
var StagingData = require('staging-data.js');
var JobParserFactory = require('job-parser-factory.js');
var FileSystemEnumerator = require('fs-enumerator.js');
var FileSystemExtractor = require('fs-extractor.js');
var path = require('path');
var config = require('config.js');
var winston = require('winston');
winston.level = config.loggingLevel;

function importStructured(baseDirectory, callback) {
    var pathQueue = new Array();

    config.topics.forEach(function (selectedTopic) {
        config.platforms.forEach(function (selectedPlatform) {
            var currentPath = path.join(baseDirectory, selectedTopic, selectedPlatform);
            FileSystemEnumerator.traverseDir(currentPath,   selectedPlatform,   selectedTopic,
pathQueue);
        })
    });

    consumePathQueue(pathQueue, callback);
}

function importSingle(baseDirectory, platformName, callback) {
     var pathQueue = new Array();

    // check single directory only
    if (platformName) {
        FileSystemEnumerator.traverseDir(baseDirectory, platformName, null, pathQueue);
        consumePathQueue(pathQueue, callback);
    } else {
        // without a platform name, we can't select a parser
        // therefore, abort
        callback(new Error('No platform name specified'));
        return;
    }
}

function consumePathQueue(pathQueue, callback) {
    var stagingQueue = new Array();
    var parserManager = new JobParserFactory();

    if ((!pathQueue) || (pathQueue.length == 0)) {
        callback(new Error('Nothing to process'));
        return;
    }

    while (pathQueue.length > 0) {
        var currentElement = pathQueue.shift();
        winston.debug('Pop ' + currentElement[0]);
        var stagingObject = FileSystemExtractor.createObject(currentElement, parserManager);
        stagingQueue.push(stagingObject);
        winston.debug('Staging object with id ' + stagingObject.sourceId + ' from ' + stag-
ingObject.url);
    }

    callback(null, stagingQueue);
}

var interfaceDefinition = {
    importStructured: importStructured,
    importSingle: importSingle
};

module.exports = interfaceDefinition;
```

B.2.11 Data Analysis (analysis-data.js)

```
var StagingData = require('staging-data.js');

/* Constructor takes optional argument of type StagingData to enable clients to transfer
** data with a single call */
var AnalysisData = function(optionalArg) {
   if (optionalArg && (optionalArg instanceof StagingData)) {
      this.id = optionalArg.id;
      this.source = optionalArg.source;
      this.sourceId = optionalArg.sourceId;
      this.searchTerm = optionalArg.searchTerm;
   } else {
      this.id = 0;
      this.source = null;
      this.sourceId = null;
      this.searchTerm = null;
   }

   this.title = null;
   this.location = null;
   this.type = null;
   this.hours = null;
   this.company = null;
   this.postingBody = null;
   this.mimeType = 'text/html';
};

AnalysisData.prototype = {
   getSummary : function() {
      return '**\tJob posting object #' + this.id + ' - ' + this.type + ' and ' + this.hours
      + '\n\twith title "' + this.title + '"\n\tat '
      + this.company + '\n\tin ' + this.location
      + '\n\tBody: ' + this.getPostingPreview();
   },
   // auxiliary function for getSummary
   getPostingPreview : function() {
      if (this.postingBody) {
         return this.postingBody.slice(0,50) + '...';
      } else {
         return '*empty*';
      }
   },
   getShortenedTitle : function() {
      if ((this.title) && (this.title.length > 50)) {
         return this.title.slice(0,50) + '...';
      } else {
         return this.title;
      }
   },
   // return values to be stored in database table,
   // to be passed to the database client for insertion
   toArray : function () {
      return [
         this.source,
         this.sourceId,
         this.searchTerm,
         this.title,
         this.location,
         this.type,
         this.hours,
         this.company,
         this.postingBody,
         'text/html'
      ];
   }
};

module.exports = AnalysisData;
```

B.2.12 Job Parser (job-parser-factory.js)

```
var StagingData = require('staging-data.js');
var AnalysisData = require('analysis-data.js');
var MonsterParser = require('monster-parser.js');
var StepstoneParser = require('stepstone-parser.js');
var StellenanzeigenParser = require('stellenanzeigen-parser.js');
var config = require('config.js');
var winston = require('winston');
winston.level = config.loggingLevel;

var JobParserFactory = function() {
   this.parsers = Object.create(Object.prototype);
};

JobParserFactory.prototype = {
   getConcreteParser : function(platform) {
      if (this.parsers.hasOwnProperty(platform) && this.parsers[platform]) {
         winston.debug('Found parser for ' + platform);
         return this.parsers[platform];
      } else {
         switch(platform) {
            case 'monster':
               this.parsers[platform] = new MonsterParser();
               return this.parsers[platform];
               break;
            case 'stepstone':
               this.parsers[platform] = new StepstoneParser();
               return this.parsers[platform];
               break;
            case 'stellenanzeigen':
               this.parsers[platform] = new StellenanzeigenParser();
               return this.parsers[platform];
               break;
         }
      }

      return null;
   }
};

module.exports = JobParserFactory;
```

B.2.13 Verifier (verifier.js)

```
var config = require('config.js');
var LanguageDetect = require('languagedetect');
var languageDetector = new LanguageDetect();
var winston = require('winston');
winston.level = config.loggingLevel;


var regularExpressionArray = [
   /industrie[-_\s]{0,1}4\.0/gi,
   /internet[-_\s]{0,1}of[-_\s]{0,1}things/gi,
   /internet[-_\s]{0,1}der[-_\s]{0,1}dinge/gi,
   /digitalisierung/gi,
   /digital[e]{0,1}[-_\s]{0,1}transformation/gi,
   /digital business transformation/gi,
   /IoT|IdD/g
];

/* Returns the number of times any of the key terms
**  appears in the string
**
**  only for internal use */
function getKeyTermOccurrences(inputString) {
   var numberOfMatches = 0;
   regularExpressionArray.forEach(function (currentRegex) {
      var matchingResult = inputString.match(currentRegex);
      numberOfMatches += (matchingResult) ? matchingResult.length : 0;
   })

   return numberOfMatches;
```

```
}

function titleIsRelevant(titleString) {
    return (getKeyTermOccurrences(titleString) >= config.requiredKeyTermsInTitle);
}

function postingBodyIsRelevant(bodyString) {
    return (getKeyTermOccurrences(bodyString) >= config.requiredKeyTermsInBody);
}

/* Returns a language string for a given inputString
**
** Returns the result with the highest confidence,
** irrespective of the actual level */
var getLanguage = function (inputString) {
   var mostLikelyLanguage = null;

   var resultArray = languageDetector.detect(inputString, 3);
   winston.debug(resultArray);
   if (resultArray) {
      mostLikelyLanguage = resultArray[0][0];
   }

   return mostLikelyLanguage;
}

/* Checks (bool) whether inputString is in a certain language
**
** A defensive approach is used by default, returning false only if
** another language has been detected with high confidence */
var isInLanguage = function (inputString, languageToCheck, options) {
   var defensiveMode = true;
   var confidenceDiffThreshold = 0.05;

   if (options && (typeof options.defensiveMode !== 'undefined')) {
      defensiveMode = options.defensiveMode;
      winston.debug('Language Mode Option set to ' + defensiveMode);
   }

   if (options && (typeof options.confidenceDiffThreshold !== 'undefined')) {
      confidenceDiffThreshold = options.confidenceDiffThreshold;
      winston.debug('Threshold Option set to ' + confidenceDiffThreshold);
   }

   var boolReturn = true;
   languageToCheck = languageToCheck.toLowerCase();

   var resultArray = languageDetector.detect(inputString, 2);
   winston.debug(resultArray);

   if (resultArray && resultArray[0] && resultArray[1]) {
      var mostLikelyLanguage = resultArray[0][0];
      var rank1Confidence = resultArray[0][1];
      var rank2Confidence = resultArray[1][1];
      var confidenceDiff = rank1Confidence - rank2Confidence;
      if (defensiveMode) {
         // defensive mode on
         // expected language is assumed unless another language surpasses
         // the next highest confidence value by confidenceDiffThreshold
         if ((mostLikelyLanguage != languageToCheck) && (confidenceDiff > confidenceDiffThresh-
old)) {
            boolReturn = false;
         }
      } else {
         // defensive mode off
         // detected language must be expected language and ahead by confidenceDiffThreshold
         boolReturn = false;
         if ((mostLikelyLanguage == languageToCheck) && (confidenceDiff > confidenceDiffThresh-
old)) {
            boolReturn = true;
         }
      }
   }

   return boolReturn;
```

```
}

var interfaceDefinition = {
   titleIsRelevant : titleIsRelevant,
    postingBodyIsRelevant : postingBodyIsRelevant,
   isInLanguage : isInLanguage,
   getKeyTermOccurrences
};

module.exports = interfaceDefinition;
```

B.2.14 List Parser (list-parser-factory.js)

```
var StagingData = require('staging-data.js');
var AnalysisData = require('analysis-data.js');
var MonsterListParser = require('list-monster.js');
var StepstoneListParser = require('list-stepstone.js');
var config = require('config.js');
var RequestTask = require('request-task.js');
var winston = require('winston');
winston.level = config.loggingLevel;

var ListParserFactory = function() {
   this.parsers = Object.create(Object.prototype);
};

ListParserFactory.prototype = {
   getConcreteParser : function(platform) {
      if (this.parsers.hasOwnProperty(platform) && this.parsers[platform]) {
         winston.debug('Found list parser for ' + platform);
         return this.parsers[platform];
      } else {
         switch(platform) {
            case 'monster':
               this.parsers[platform] = new MonsterListParser();
               return this.parsers[platform];
               break;
            case 'stepstone':
               this.parsers[platform] = new StepstoneListParser();
               return this.parsers[platform];
               break;
         }
      }

      return null;
   }
};

module.exports = ListParserFactory;
```

B.2.15 Utilize (util.js)

```
var cheerio = require('cheerio');
var HtmlEntities = require('html-entities').AllHtmlEntities;
var htmlEntities = new HtmlEntities();

var regularExpressions = {
   htmlComments : /<!--[\S\s]+?-->/g,
   lineBreaks : /\n|\r|\r\n/g,
   whitespace : /[\s]{2,}/g,
   htmlFile : /[\s\S]+.htm[l]{0,1}$/
}

/* Main cleanup function
**
** Accepts strings or jQuery objects, always returns a string.
** Removes HTML elements which are unlikely to contain relevant text
** by invoking jQuery and various helper methods */
var stripAll = function (inputObj) {
   var $ = prepareInput(inputObj);

   $('head').empty().remove();
   $('style').empty().remove();
   $('link').remove();
```

```
   $('img').remove();
   $('object').remove();
   $('embed').remove();
   $('script').remove();
   $('a[onclick^="javascript"]').remove();

   $('li').replaceWith(function() {
      return '. ' + $(this).contents() + '. '
   })
   $('strong').replaceWith(function() {
      return $(this).contents();
   })
   $('font').replaceWith(function() {
      return $(this).contents();
   })
   $('br').replaceWith(function() {
      return $(this).contents() + ' . ';
   })

   var htmlStringCleaned = cleanNonElements($('*').html());
   var htmlStringTrimmed = stripWhitespace(htmlStringCleaned);
   var htmlStringConverted = convertHtmlEntities(htmlStringTrimmed);

   return htmlStringConverted;
};

/* Removes superfluous whitespace
**
** Converts multiple characters of whitespace to a single one
** and removes leading/trailing whitespace entirely */
var stripWhitespace = function (inputString) {
   if (!inputString) {
      return inputString;
   }
   var stringWithoutExcessiveWhitespace = inputString.replace(regularExpressions.whitespace, '
');
   var stringTrimmed = stringWithoutExcessiveWhitespace.trim();
   return stringTrimmed;
}

/* Performs miscellaneous cleanup duties
**
** Removes HTML comments <!-- -->
** and line breaks (Win/Mac/Unix styles) */
var cleanNonElements = function (inputString) {
   if (!inputString) {
      return inputString;
   }
   var stringWithoutComments = inputString.replace(regularExpressions.htmlComments, '');
   var  stringWithoutNewLines  =  stringWithoutComments.replace(regularExpressions.lineBreaks,
'');
   return stringWithoutNewLines;
}

/* Converts HTML entities back to Unicode
**
** Especially important for tokens containing diacritics */
var convertHtmlEntities = function (inputString) {
   if (!inputString) {
      return inputString;
   }
   var stringWithoutEntities = htmlEntities.decode(inputString);
   return stringWithoutEntities;
}

/* Prepares input for treatment with jQuery
**
** If inputObj is not already a jQuery/cheerio object,
** the string is surrounded with wrapper elements and
** passed to the jQuery constructor */
var prepareInput = function (inputObj) {
   var jQueryObj = null;

   if('jquery' in Object(inputObj)) {
      //console.log('if branch');
```

```
      jQueryObj = inputObj;
   } else {
      //console.log('else branch');
      if (inputObj) {
         inputObj = inputObj.trim();
      }
      inputObj = '<body>' + inputObj + '</body>';
      var $ = cheerio.load(inputObj, {decodeEntities:false});
      jQueryObj = $('*');
   }

   return $;
}

/* Checks whether a given file name ends in htm or html */
var isHtmlPath = function (inputString) {
   return inputString.match(regularExpressions.htmlFile);
}


var util = {
   stripElements : stripAll,
   stripWhitespace : stripWhitespace,
   isHtmlPath : isHtmlPath
};

module.exports = util;
```

B.2.16 Queue Cleaner (queue-cleaner.js)

```
var RequestTask = require('request-task.js');
var config = require('config.js');
var async = require ('async');
var verifier = require('verifier');
var _ = require('lodash');
var winston = require('winston');
winston.level = config.loggingLevel;

/*  External interface
**
**  Starts three parallel cleaning tasks:
**  - Postings that are already queued for crawling,
**  - postings that have already been parsed, and
**  - postings whose title does not match the term criterion*/
function cleanQueue(taskQueue, candidateQueue, platform, hanaClient, eventualCallback) {
    async.parallel([
        generateIdArrayFromTaskQueue.bind(null, taskQueue),
        generateIdArrayForInvalidTitles.bind(null, candidateQueue),
        fetchExistingIdsFromDb.bind(null, platform, candidateQueue, hanaClient)
    ], mergeIdArrays.bind(null, candidateQueue, eventualCallback));
}

function generateIdArrayFromTaskQueue(taskQueue, parallelCallback) {
    async.map(taskQueue, extractIdFromRequestTask, parallelCallback);
}

function extractIdFromRequestTask(taskObject, mapCallback) {
    var extractedId = 0;
    if (taskObject && (taskObject instanceof RequestTask)) {
        extractedId = taskObject.sourceId;
    }
    mapCallback(null, extractedId);
}

// start filtering by keyword occurrences in titles
function generateIdArrayForInvalidTitles(candidateQueue, parallelCallback) {
    async.filter(candidateQueue, getTitleValidity, handleTasksWithInvalidTitle.bind(null, par-
allelCallback));
}

// keep elements (pass true to callback) which do not have the
// required number of keywords to subsequently extract their IDs
function getTitleValidity(taskObject, filterCallback) {
    filterCallback(null, !(verifier.titleIsRelevant(taskObject.title)));
}
```

```
// continue the same way as with task queue for first branch
// i.e. by generating id array and passing it to mergeIdArrays
function handleTasksWithInvalidTitle(parallelCallback, err, results) {
    generateIdArrayFromTaskQueue(results, parallelCallback);
}

// start database query for records with the same platform and ID
// as those in the candidate queue
function fetchExistingIdsFromDb(platform, candidateQueue, hanaClient, parallelCallback) {
    async.waterfall([
        generateIdArrayFromTaskQueue.bind(null, candidateQueue),
        launchDbQuery.bind(null, platform, hanaClient),
        generateIdArrayFromDbResult
    ], parallelCallback);
}

// send select query and pass result to generateIdArrayFromDbResult
function launchDbQuery(platform, hanaClient, idArray, waterfallCallback) {
    winston.debug('Launching database query for platform ' + platform + ' and IDs ' + idArray);

    hanaClient.selectSourceIds(platform, idArray, waterfallCallback);
}

// extract ID (SOURCEID field) from each database result object
// and pass result to waterfall, which will pass the result
// to mergeIdArrays
function generateIdArrayFromDbResult(result, waterfallCallback) {
    async.map(result, extractIdFromResultObj, waterfallCallback);
}

// extract SOURCEID property from database result object and
// pass it back to async.map
function extractIdFromResultObj(resultElement, mapCallback) {
    var extractedId = 0;
    if (resultElement && ('SOURCEID' in resultElement)) {
        extractedId = resultElement.SOURCEID;
    }
    mapCallback(null, extractedId);
}

// accept the three partial arrays containing source IDs of tasks
// that have been selected in the individual tests, merge them while (condition) {
// discarding duplicates and then initiate their removal from the
// candidate task queue
function mergeIdArrays(candidateQueue, eventualCallback, err, results) {
    if (err) {
        eventualCallback(err);
        return;
    }

    if ((results) && (results.length == 3)) {
        var mergedArray = _.union(results[0], results[1], results[2]);
        winston.debug('Items already in queue: ' + results[0]);
        winston.debug('Items with invalid title: ' + results[1]);
        winston.debug('Items already processed: ' + results[2]);
        winston.debug('Merged ID blacklist array: ' + mergedArray);
    }

    if (_.isArray(mergedArray)) {
        winston.debug('Removing ' + mergedArray.length + ' unique IDs from candidate queue');
        async.filter(candidateQueue,      filterWorker.bind(null,      mergedArray),      re-
sultHandler.bind(null, eventualCallback));
    } else {
        winston.debug('Error while filtering, returning candidate queue unchanged');
        eventualCallback(null, candidateQueue);
    }
}

// keep elements which have not been marked for removal
function filterWorker(blacklistArray, candidateElement, filterCallback) {
    filterCallback(null, !(_.includes(blacklistArray, candidateElement.sourceId)));
}

// hand back control to callback set by caller
```

```
// (handleFilteredQueue in crawler)
function resultHandler(eventualCallback, err, result) {
    winston.debug('resultHandler');
    winston.debug(result);
    eventualCallback(null, result);
}

var interfaceDefinition = {
    cleanQueue : cleanQueue
};

module.exports = interfaceDefinition;
```

B.2.17 File System Enumerator (fs-enumerator.js)

```
var fs = require('fs');
var path = require('path');
var util = require('util.js');
var config = require('config.js');
var winston = require('winston');
winston.level = config.loggingLevel;

/* Function traverseDir expects as 'baseDirectory' a path
 **   of the format JobPostingsRoot/SearchTerm/Platform and,
 **   for all first-level child directories, checks whether
 ** they contain the necessary files for parsing.
 ** Pushes valid paths to 'queue' */
var traverseDir = function (baseDirectory, platform, searchTerm, queue) {
   if (!fs.existsSync(baseDirectory)) {
      // skip nonexisting directory
      winston.error('Directory "' + baseDirectory + '" not found.');
      return;
   } else {
      winston.info('Traversing ' + baseDirectory + '...');
   }
   // normalize platform string (e.g. 'monster')
   platform = platform.toLowerCase();
   // read contents of base directory (files and directories)
   var allChildElements = fs.readdirSync(baseDirectory);


   allChildElements.forEach(function (currentElement) {
      var fullPath = path.join(baseDirectory, currentElement);
      // check for direct subfolders with the necessary files in them
      if (fs.statSync(fullPath).isDirectory()) {
         var numContent = fs.readdirSync(fullPath).length;
         if (numContent > 1) {
            // closer inspection of candidate directories
            // check for presence of expected files
            var containsPageSource = fs.existsSync(path.join(fullPath, 'page.html'));
            var containsUrl = fs.existsSync(path.join(fullPath, 'url.txt'));
            var containsFrameSource = fs.existsSync(path.join(fullPath, 'iframe.html'));
            if (containsPageSource && containsUrl) {
               queue.push([fullPath, platform, searchTerm, containsFrameSource]);
            }
         }
      }
      // check HTML files in base directory
      if (fs.statSync(fullPath).isFile() && util.isHtmlPath(currentElement)) {
         queue.push([fullPath, platform, searchTerm, false]);
      }
   })
};

var interfaceDefinition = {
   traverseDir: traverseDir
};

module.exports = interfaceDefinition;
```

B.2.18 File System Extractor (fs-extractor.js)

```
var StagingData = require('staging-data.js');
var urlParser = require('urlparser.js');
```

```
var JobParserFactory = require('job-parser-factory.js');
var util = require('util.js');
var fs = require('fs');
var path = require('path');

/* Function createObject accepts a data structure (contents
 **   are explained below), reads the saved web page from disk
 **   and wraps the result in a StagingData object, which can then
 ** be persisted and processed */
var createObject = function (paramArray, parserManager) {
   // the full path up to the directory containing the files
   var fullPath = paramArray[0];
   // the job platform (e.g. monster, stepstone) which is the source of the given
   // data
   var platform = paramArray[1];
   if ((platform instanceof String) || (typeof platform === 'string')) {
      // normalize string for downstream functions
      var platform = platform.toLowerCase();
   }
   // the search term used to find the posting (e.g. 'Internet of Things')
   var searchTerm = paramArray[2];
   // whether the caller has detected the presence of an iframe
   var hasIframe = paramArray[3];

   var returnObject = new StagingData();
   var parser = parserManager.getConcreteParser(platform);

   if (util.isHtmlPath(fullPath)) {
      // this entry is a single HTML file, not a folder
      var pageHtml = fs.readFileSync(fullPath, 'utf8');
      // extract URL from source since we do not have a separate
      // URL file
      var dirtyUrl = parser.extractUrl(pageHtml);

   } else {
      // a subfolder according to our predefined structure
      // expects the saved web page as 'page.html'
      var pageHtml = fs.readFileSync(path.join(fullPath, 'page.html'), 'utf8');
      // expects the full URL as the first line in 'url.txt'
      var dirtyUrl = fs.readFileSync(path.join(fullPath, 'url.txt'), 'utf8').split('\n')[0];

   }

   if (dirtyUrl) {
      var urlObject = urlParser.parse(platform, dirtyUrl);
      returnObject.sourceId = urlObject.listingId;
      returnObject.url = urlObject.cleanUrl
   }

   returnObject.searchTerm = searchTerm;
   returnObject.pageHtml = pageHtml;
   returnObject.source = platform;

   if (hasIframe) {
      returnObject.frameHtml = fs.readFileSync(path.join(fullPath, 'iframe.html'), 'utf8');
   }

   return returnObject;
};

var interfaceDefinition = {
   createObject: createObject
};

module.exports = interfaceDefinition;
```

B.2.19 Parser for Monster (monster-parser.js)

```
var cheerio = require('cheerio');
var util = require('util.js');
var AnalysisData = require('analysis-data.js');

var MonsterParser = function () {
```

```
};

MonsterParser.prototype = {
   parse: function (stagingObject) {
      var analysisObject = new AnalysisData(stagingObject);

      var $ = cheerio.load(stagingObject.pageHtml);

      // Variables to hold intermediate jQuery objects
      var jqTitle, jqLocation, jqType, jqCompany, jqPosting;

      if ($('div').hasClass('jobview-section')) {
         // modern, 'found at' layout with reduced info content

         jqTitle = $('header.jobview-header h3');
         analysisObject.title = util.stripWhitespace(jqTitle.text());

         var subtitle = $('header.jobview-header h4.company');
         var subtitleString = subtitle.text();
         var subtitleArray = subtitleString.match(/Gefunden bei:([\S\s]+) - ([\S\s]+)/);

         if (subtitleArray && (subtitleArray.length > 2)) {
            analysisObject.company = util.stripWhitespace(subtitleArray[1]);
            analysisObject.location = util.stripWhitespace(subtitleArray[2]);
         }

         jqPosting = $('div.jobview-section');
         analysisObject.postingBody = util.stripElements(jqPosting.text());

      } else {
         // classic layout which contains JobPosting meta data
         $('div[itemtype="http://schema.org/JobPosting"]').first().each(function () {

            jqTitle = $(this).find('meta[itemprop="title"]');
            var titleString = jqTitle.prop("content");
            if (!titleString) {
               // fall back on hidden form at the bottom of the page
               jqTitle = $('#jobPosition');
               titleString = jqTitle.prop("value");
            }
            analysisObject.title = util.stripWhitespace(titleString);

            jqLocation = $(this).find('meta[itemprop="joblocation"]');
            var locationString = jqLocation.prop("content");
            if (!locationString) {
               // fall back on hidden form
               jqLocation = $('#jobLocation');
               locationString = jqLocation.prop("value");
            }
            analysisObject.location = locationString;

            jqType = $(this).find('meta[itemprop="employmenttype"]');
            var typeHoursCombined = jqType.prop("content");
            if (typeHoursCombined) {
               var typeHoursArr = typeHoursCombined.split(',');
               var typeString = typeHoursArr[1];
               if (typeString) {
                  analysisObject.type = typeString.trim();
               }

               var hoursString = typeHoursArr[0];
               if (hoursString) {
                  analysisObject.hours = hoursString.trim();
               }
            }

            jqCompany    =    $(this).find('span[itemprop="hiringOrganization"]    meta[item-
prop="name"]');
            var companyString = jqCompany.prop("content");
            if (!companyString) {
               // fall back on hidden form
               jqCompany = $('#jobCompany');
               companyString = jqCompany.prop("value");
            }
```

```
            analysisObject.company = companyString;
         });

         jqPosting = $('#TrackingJobBody');
         if ((!jqPosting) || (jqPosting.length == 0)) {
            // fall back on wrapper element higher up in DOM tree
            jqPosting = $('#monsterAppliesContentHolder');
            // additional cleanup to remove sidebar and duplicate content
            jqPosting.find('#iaactionfixed, #iaaction').remove();
            jqPosting.find('meta').empty().remove();
            jqPosting.find('div[itemtype="http://schema.org/JobPosting"]').remove();
         }

         analysisObject.postingBody = util.stripElements(jqPosting.html());
      }

      return analysisObject;
   },
   extractUrl: function (htmlSource) {
      // if the url has not been specified externally, it needs to be extracted
      // from the HTML source as well
      var $ = cheerio.load(htmlSource);
      var urlString;

      urlString = $('link[rel="canonical"]').prop('href');

      if (!urlString) {
         // htmlSource is not a standard monster job posting, but
         // probably using the new layout
         // try and extract URL from recommendation link
         var mailtoLink = $('a[href^="mailto: ?subject="]').prop('href');
         var urlRegex = /http:\/\/stellenangebot\.monster\.de\/[\S]*\?mescoid=[\d]*/;
         var candidateMatch = mailtoLink.match(urlRegex);
         if (candidateMatch) {
            // select entire match
            // urlString is expected to be passed to urlParser afterwards
            urlString = candidateMatch[0];
         }
      }

      return urlString;
   },
   extractIframeUrl: function (htmlSource, pageUrl) {
      return null;
   }
};

module.exports = MonsterParser;
```

B.2.20 Parser for StepStone (stepstone-parser.js)

```
var url = require('url');
var cheerio = require('cheerio');
var util = require('util.js');
var AnalysisData = require('analysis-data.js');

var StepstoneParser = function () {

};

StepstoneParser.prototype = {
   parse: function (stagingObject) {
      var analysisObject = new AnalysisData(stagingObject);

      var $ = cheerio.load(stagingObject.pageHtml);

      // indicator variable to determine from which field
      // to read the actual job posting
      var iframeDetected = false;
      iframeDetected = ($('iframe').hasClass('listing__html_jobcontentframe'))
         || ($('iframe').hasClass('listing__template_jobcontentframe'));

      // class names only present in modern layout
```

```
      var isNewLayout = ($('div.listing__main-content').length)
         || ($('div').hasClass('listing__top-info'));

      // variables to hold intermediate jQuery objects
      var jqTitle, jqLocation, jqType, jqHours, jqCompany, jqPosting;

      if (isNewLayout) {
         // start by traversing the meta data in the 'info box'
         // above the actual posting
         $('div.listing__top-info').first().each(function () {
            jqTitle = $(this).find('h1.listing__job-title');
            var titleString = jqTitle.text();
            analysisObject.title = titleString;

            // elements apart from title are all siblings
            // find first element and traverse in order
            jqLocation = $(this).find('ul.listing__list-icons').children().first();
            var locationString = jqLocation.text();
            analysisObject.location = locationString.trim();

            jqType = jqLocation.next();
            var typeString = jqType.text();
            analysisObject.type = typeString.trim();

            jqHours = jqType.next();
            var hoursString = jqHours.text();
            analysisObject.hours = hoursString.trim();

            jqCompany = $(this).find('h6.listing__company-name a');
            var companyString = jqCompany.text();
            analysisObject.company = companyString;
         })

         // modern layout exists with inline content as well as iframe
         if (iframeDetected) {
            analysisObject.postingBody = util.stripElements(stagingObject.frameHtml);
         } else {
            jqPosting = $('div.listing__main-content');
            if ((!jqPosting) || (jqPosting.length == 0)) {
               // fall back on wrapper element higher up in DOM tree
               jqPosting = $('div.listing-content');
               // additional cleanup to remove header info that
               // has already been parsed above as well as media content
               jqPosting.find('div.listing-header').empty().remove();
               jqPosting.find('div.card__media').empty().remove();
            }
            analysisObject.postingBody = util.stripElements(jqPosting.html());
         }
      } else {
         // 'v5' legacy layout
         // start by traversing the meta data in the 'left sidebar'
         $('#offerInformation').first().each(function () {
            jqLocation = $(this).find('span[itemprop="jobLocation"] span[itemprop="name"]');
            var locationString = jqLocation.text();
            analysisObject.location = locationString;

            // there are two span elements with an employmentType property
            // only distinguishable by examining the preceding section heading,
            // which - in addition - is localized
            jqType = $(this)
               .find('div.h3:contains("Anstellungsart"), div.h3:contains("Contract")')
               .nextUntil('span[itemprop="employmentType"]').next();
            var typeString = jqType.text();
            analysisObject.type = typeString;

            jqHours  =  $(this).find('div.h3:contains("Arbeitszeit"),  div.h3:contains("Stat-
ute")')
               .next();
            var hoursString = jqHours.text();
            analysisObject.hours = hoursString;
         })

         jqTitle = $('div.listing h1.offer_title');
         var titleString = jqTitle.text();
         analysisObject.title = titleString;
```

```
         jqCompany = $('#companyPresentationLink span');
         var companyString = jqCompany.text();
         analysisObject.company = companyString;

         jqPosting = $('#jobOfferWrapper');
         analysisObject.postingBody = util.stripElements(jqPosting.html());
      }

      return analysisObject;
   },
   extractUrl: function (htmlSource) {
      // if the url has not been specified externally, it needs to be extracted
      // from the HTML source as well
      var $ = cheerio.load(htmlSource);
      var urlString;

      urlString = $('link[rel="canonical"]').prop('href');

      return urlString;
   },
   extractIframeUrl: function (htmlSource, pageUrl) {
      var iframeUrl = null;
      var $ = cheerio.load(htmlSource);

      if (!pageUrl) {
         pageUrl = this.extractUrl(htmlSource);
      }
      var urlObject = url.parse(pageUrl);

      var iframe = $('iframe.listing__html_jobcontentframe');
      if ((!iframe) || (iframe.length == 0)) {
         iframe = $('iframe.listing__template_jobcontentframe');
      }

      if (iframe && (iframe.length > 0)) {
         candidateIframeUrl = iframe.prop('src');
         if (candidateIframeUrl && (candidateIframeUrl.substring(0, 1) === '/')) {
            var baseUrl = urlObject.protocol + ((urlObject.slashes) ? '//' : '') + urlOb-
ject.host;
            iframeUrl = url.resolve(baseUrl, candidateIframeUrl);
         } else if (candidateIframeUrl) {
            iframeUrl = candidateIframeUrl;
         }
      }

      return iframeUrl;
   }
};

module.exports = StepstoneParser;
```

B.2.21 Parser for Job Offers (stellenanzeigen-parser.js)

```
var cheerio = require('cheerio');
var util = require('util.js');
var StagingData = require('staging-data.js');
var AnalysisData = require('analysis-data.js');

var StellenanzeigenParser = function() {

};

StellenanzeigenParser.prototype = {
   parse : function(stagingObject) {
      var analysisObject = new AnalysisData(stagingObject);

      var $ = cheerio.load(stagingObject.pageHtml);

      // variables to hold intermediate jQuery objects
      var jqTitle, jqMetaDescription;

      jqTitle = $('meta[property="og:title"]');
      var titleString = jqTitle.prop("content");
```

```
      analysisObject.title = titleString;

      jqMetaDescription = $('meta[property="og:description"]');
      var metaDescriptionArr = jqMetaDescription.prop('content').split(' / ');

      var locationString = metaDescriptionArr[1];
      analysisObject.location = locationString;

      var companyString = metaDescriptionArr[0];
      analysisObject.company = companyString;

      analysisObject.postingBody = util.stripElements(stagingObject.frameHtml);

      return analysisObject;
   },
   extractUrl: function (htmlSource) {
      // if the url has not been specified externally, it needs to be extracted
      // from the HTML source as well
      var $ = cheerio.load(htmlSource);
      var urlString;

      urlString = $('link[rel="canonical"]').prop('href');

      return urlString;
   },
   extractIframeUrl: function (htmlSource, pageUrl) {
      return null;
   }
};

module.exports = StellenanzeigenParser;
```

B.2.22 Parser for Monster Lists (list-monster.js)

```
var fs = require('fs');
var path = require('path');
var url = require('url');
var querystring = require('querystring');
var cheerio = require('cheerio');
var config = require('config.js');
var RequestTask = require('request-task.js');
var winston = require('winston');
winston.level = config.loggingLevel;

var baseUrl = 'http://www.monster.de';
var basePath = '/jobs/suche/';
var platform = 'monster';


var MonsterListParser = function () {

};

MonsterListParser.prototype = {
   parseResultList: function (content, taskQueue, searchTerm) {
      var context = this;
      var $ = cheerio.load(content);

      var linksContainingTitle = $('h2 a[onMouseDown*="Title Link Click"]');
      winston.debug('number of matching links: ' + linksContainingTitle.length);

      if (linksContainingTitle.length > 0) {
         // result list rendered with JavaScript-enabled browser

         linksContainingTitle.each(function () {
            var title = $(this).prop('title');
            var pageUrl = $(this).prop('href');

            var tempObj = new RequestTask();
            tempObj.source = platform;
            tempObj.title = title;
            tempObj.searchTerm = searchTerm;
            tempObj.setPageUrl(pageUrl);

            taskQueue.push(tempObj);
```

```
            winston.debug(tempObj);
         });
      } else {
         // raw data as received by request module
         var jsonElements = $('script[type="application/ld+json"]');
         winston.debug('number of JSON-LD tags: ' + jsonElements.length);
         jsonElements.each(function () {
            var tempObj = context.parseJsonLd($(this).text());
            if (tempObj) {
               tempObj.source = platform;
               tempObj.searchTerm = searchTerm;
               // re-set value to trigger URL parsing
               tempObj.setPageUrl(tempObj.pageUrl);
               taskQueue.push(tempObj);
               winston.debug(tempObj);
            }
         })
      }
   },
   parseJsonLd: function (inputString) {
      var fullObject = JSON.parse(inputString);
      //console.log(fullObject);
      if (fullObject['@type'] === 'JobPosting') {
         var task = new RequestTask();

         task.pageUrl = fullObject.url;
         task.title = fullObject.title;

         return task;
      } else {
         return null;
      }
   },
   getNumberOfResults: function (firstPageHtml) {
      var $ = cheerio.load(firstPageHtml);
      var numberOfResults = null;

      var foundJobsContainer = $('h2.page-title.visible-xs');
      var foundJobsString = foundJobsContainer.text().trim();
      winston.debug('ERROR:'+foundJobsString);
      var jobsRegex = /([\d]{1,4})[\+]{0,1} Jobs gefunden/;
      jobsRegex = /([\d]{1,4})[\+]{0,1} passende Jobs gefunden/;
      var resultArray = foundJobsString.match(jobsRegex);
      if (resultArray.length > 1) {
         numberOfResults = resultArray[1];
      }

      return numberOfResults;
   },
   generateInitialResultListUrl: function (searchTerm, shouldSortByDate) {
      var urlObject = url.parse(baseUrl + basePath);
      var queryObject = {
         q : '"' + searchTerm + '"',
         sort : (shouldSortByDate) ? 'dt.rv.di' : 'rv.dt.di'
      }

      return this.getUrlWithQuery(urlObject, queryObject);
   },
   // note: bounds checking is the caller's responsibility
   generateNextResultListUrl: function (currentUrl) {
      var urlObject = url.parse(currentUrl);
      var originalQueryString = urlObject.query;
      var queryObject = querystring.parse(originalQueryString);

      if (queryObject['page']) {
         winston.debug('current result page: ' + queryObject['page']);
         queryObject['page'] = parseInt(queryObject['page']) + 1;
      } else {
         // the page number is not explicitly contained in the URL
         // i.e. we're on the first page, simply append page argument
         queryObject['page'] = 2;
      }

      winston.debug('new result page: ' + queryObject['page']);
      return this.getUrlWithQuery(urlObject, queryObject);
```

```
   },
   getUrlWithQuery: function (urlObject, queryObject) {
      urlObject.search = undefined;
      urlObject.query = queryObject;
      return url.format(urlObject);
   }
}

module.exports = MonsterListParser;
```

B.2.23 Parser for StepStone Lists (list-stepstone.js)

```
var fs = require('fs');
var path = require('path');
var url = require('url');
var querystring = require('querystring');
var cheerio = require('cheerio');
var config = require('config.js');
var RequestTask = require('request-task.js');
var winston = require('winston');
winston.level = config.loggingLevel;

var baseUrl = 'https://www.stepstone.de';
var basePath = '/5/ergebnisliste.html';
var platform = 'stepstone';

var StepstoneListParser = function () {

};

StepstoneListParser.prototype = {
   parseResultList: function (content, taskQueue, searchTerm) {
      var $ = cheerio.load(content);

      var resultHeaders = $('div.job-element-row');//Aktualisiert am 02.11.2017
      winston.debug('number of matching links: ' + resultHeaders.length);

      if (resultHeaders.length > 0) {
         // list items found, extract relevant data

         resultHeaders.each(function () {
            var  title  =  $(this).find('h2.job-element__body__title').text();//Aktualisiert  am
02.11.2017
            // all other links contain relative URLs
            var pageUrl = $(this).find('a[href^="https://www.stepstone.de"]').prop('href');

            var tempObj = new RequestTask();
            tempObj.source = platform;
            tempObj.title = title;
            tempObj.searchTerm = searchTerm;
            tempObj.setPageUrl(pageUrl);

            taskQueue.push(tempObj);
            winston.debug(tempObj);
         });
      }
   },
   getNumberOfResults: function (firstPageHtml) {
      var $ = cheerio.load(firstPageHtml);
      var numberOfResults = null;

      var dataDiv = $('div[data-resultlist-offers-main]');
      numberOfResults = dataDiv.prop('data-resultlist-offers-main');

      if (!numberOfResults) {
         var headerContainer = $('p.mb--xxs[data-jssswidget-headertitle]');
         if (headerContainer) {
            var numberContainer = headerContainer.find('strong');
            if (numberContainer) {
               numberOfResults = numberContainer.eq(1).text();
            }
         }
      }

      return numberOfResults;
```

```
   },
   generateInitialResultListUrl: function (searchTerm, shouldSortByDate) {
      var urlObject = url.parse(baseUrl + basePath);
      var queryObject = {
         ke : '"' + searchTerm + '"',
         ob : (shouldSortByDate) ? 'refdate' : 'relevance',
         li : 25
      }

      return this.getUrlWithQuery(urlObject, queryObject);
   },
   // note: bounds checking is the caller's responsibility
   generateNextResultListUrl: function (currentUrl) {
      var urlObject = url.parse(currentUrl);
      var originalQueryString = urlObject.query;
      var queryObject = querystring.parse(originalQueryString);

      if (queryObject['of']) {
         winston.debug('current result page start offset: ' + queryObject['of']);
         queryObject['of'] = parseInt(queryObject['of']) + 25;
      } else {
         // no offset specified, first page
         queryObject['of'] = 25;
      }

      winston.debug('new result page start offset: ' + queryObject['of']);
      return this.getUrlWithQuery(urlObject, queryObject);
   },
   getUrlWithQuery: function (urlObject, queryObject) {
      urlObject.search = undefined;
      urlObject.query = queryObject;
      return url.format(urlObject);
   }
}

module.exports = StepstoneListParser;
```

B.2.24 Request Task (request-task.js)

```
var urlparser = require('urlparser');

var RequestTask = function(optionalArg) {
   this.source = null;
   this.sourceId = null;
   this.title = null;
   this.pageUrl = null;
   this.frameUrl = null;
   this.searchTerm = null;
};

RequestTask.prototype = {
   getSummary : function () {
      return '**\tRequest task object #' + this.id
      + '\n\twith title "' + this.title
      + '\n\tPage URL: ' + this.pageUrl;
   },
   setPageUrl : function (pageUrl) {
      if (pageUrl) {
            var urlObject = urlparser.parse(this.source, pageUrl);
            if (urlObject) {
               this.pageUrl = urlObject.cleanUrl;
               this.sourceId = urlObject.listingId;
            } else {
               this.pageUrl = pageUrl;
            }
         }
   }
};

module.exports = RequestTask;
```

B.2.25 URL Parser (urlparser.js)

```
var url = require('url');
var config = require('config.js');
var winston = require('winston');
winston.level = config.loggingLevel;

var regularExpressions = {
   monsterStandard : /[\S\s]+-([\d]{6,})\.aspx/,
   monsterFound : /[\S\s]+\/monster\/([\S]{6,}(?=\?mescoid))/,
   monsterFoundCanonical : /[\S\s]+\/monster\/([\S]{6,})$/,
   stepstone : /http[\S\s]+?--([\d]{6,})-inline\.html/,
   stellenanzeigen : /[\S\s]+\/job\/([\d]{6,})\//
}

var parse = function (platform, rawUrl) {
   winston.debug('Parsing URL: ' + platform + ' -- ' + rawUrl);
   var regex = /.*/;

   if ((!platform) || (!rawUrl)) {
      return null;
   }

   switch(platform) {
      case 'monster':
         var parsedUrl = url.parse(rawUrl);
         if (parsedUrl.hostname == 'stellenanzeige.monster.de') {
            regex = regularExpressions.monsterStandard;
         };
         if (parsedUrl.hostname == 'stellenangebot.monster.de') {
            regex = regularExpressions.monsterFound;
         }
         break;
      case 'stepstone':
         regex = regularExpressions.stepstone;
         break;
      case 'stellenanzeigen':
         regex = regularExpressions.stellenanzeigen;
         break;
   }

   var retVal = rawUrl.match(regex);
   if (!retVal && (regex === regularExpressions.monsterFound)) {
      // handle canonical occurrences without query string
      retVal = rawUrl.match(regularExpressions.monsterFoundCanonical);
   }
   var matchedUrl, matchedId;
   if (retVal) {
      matchedUrl = retVal[0];
      if (retVal.length > 1) {
         matchedId = retVal[1];
      }
   } else {
      return null;
   }
   var urlObj = {
      cleanUrl : matchedUrl,
      listingId : matchedId
   }

   return urlObj;
};

var urlParser = {
   parse : parse,
   regularExpressions : regularExpressions
};

module.exports = urlParser;
```

B.2.26 Job Parser Factory (job-parser-factory.js)

```
var StagingData = require('staging-data.js');
var AnalysisData = require('analysis-data.js');
```

```
var MonsterParser = require('monster-parser.js');
var StepstoneParser = require('stepstone-parser.js');
var StellenanzeigenParser = require('stellenanzeigen-parser.js');
var config = require('config.js');
var winston = require('winston');
winston.level = config.loggingLevel;

var JobParserFactory = function() {
   this.parsers = Object.create(Object.prototype);
};

JobParserFactory.prototype = {
   getConcreteParser : function(platform) {
      if (this.parsers.hasOwnProperty(platform) && this.parsers[platform]) {
         winston.debug('Found parser for ' + platform);
         return this.parsers[platform];
      } else {
         switch(platform) {
            case 'monster':
               this.parsers[platform] = new MonsterParser();
               return this.parsers[platform];
               break;
            case 'stepstone':
               this.parsers[platform] = new StepstoneParser();
               return this.parsers[platform];
               break;
            case 'stellenanzeigen':
               this.parsers[platform] = new StellenanzeigenParser();
               return this.parsers[platform];
               break;
         }
      }

      return null;
   }
};

module.exports = JobParserFactory;
```

Appendix C: Examples for Job Offers

C.1 Example Job Offer from StepStone, Stored as PDF File

Für den Standort Düsseldorf suchen wir zum nächstmöglichen Zeitpunkt:

Senior Presales Manager (m/w) Big Data & Analytics

Altran ist globaler Marktführer im Bereich High-Tech Consulting.
Mit unseren international aufgestellten Teams treiben wir die digitale Transformation branchenübergreifend voran und schaffen Value & Innovationen für die Top-Unternehmen Deutschlands. Wenn Sie unsere Passion für Big Data & Analytics teilen und die Industrie 4.0 bei unseren Kunden maßgeblich mitgestalten möchten, dann werden Sie Teil unseres Teams.

Ihre neuen Aufgabengebiete

- Sie sind verantwortlich für die ganzheitliche technische Beratung unserer Kunden und Interessenten während der Presales-Phase über das Altran Portfolio im Bereich Big Data & Analytics
- Zur Vorstellung unserer Services und Lösungen unterstützen Sie unser Sales-Team im Rahmen von Workshops und Präsentationen bei unseren Kunden und Interessenten
- Als technischer Experte im Bereich Big Data & Analytics begleiten Sie unser Team aktiv bei der Erstellung von Angeboten und der Bearbeitung von Ausschreibungen
- Aktive Umsetzung von Marketing-Maßnahmen und Repräsentation auf Messen sowie Fachveranstaltungen
- Weiterentwicklung des Altran Portfolios im Bereich Big Data & Analytics und Unterstützung der Project Delivery-Teams bei der Definition von Kundenlösungen

Ihr passendes Profil

- Abgeschlossenes Hochschulstudium im ingenieur- oder wirtschaftswissenschaftlichen Bereich
- Mindestens 3 Jahre Erfahrung als Presales oder Solution Manager im Bereich Big Data & Analytics
- Ausgeprägte konzeptionelle, kreative und analytische Fähigkeiten, insbesondere bzgl. der Entwicklung innovativer und individueller Lösungsszenarien im Bereich Big Data & Analytics
- Exzellente Kommunikationsfähigkeit, Verhandlungsgeschick sowie Überzeugungskraft mit externen und internen Partnern in deutscher und englischer Sprache
- Eigeninitiative, Organisationstalent, Flexibilität, unternehmerisches Denken sowie nationale und internationale Reisebereitschaft

Das bieten wir Ihnen

Umfangreicher Gestaltungsspielraum und abwechslungsreiche Aufgabenfelder in industrieübergreifenden (inter-)nationalen Projekten bei den Top Unternehmen Deutschlands. Es erwartet Sie ein attraktives, mehrstufiges Karrieremodell mit Spezialisierungsmöglichkeiten sowie Fach-, Methoden- und Softskilltrainings an der Altran Academy. Zudem sorgen wir mithilfe von passgenauen Integrations- und Mentorprogrammen für Ihren gleitenden Einstieg in eine internationale Unternehmenskultur mit 26.000 Kollegen in 20 Ländern.

Haben wir Ihr Interesse geweckt?
Wir freuen uns auf Ihre Online-Bewerbung

Haben Sie noch Fragen?
Ihr Ansprechpartner:

Marco Höfler – Recruiting
Marco.Hoefler@altran.com
Tel. +49 (0) 211 179 38 123

Figure 69: Example Job Offer, Retrieved from StepStone, Stored as PDF File, German Language

C.2 Example Job Offer from Monster Worldwide, Stored as HTML File

Gehen Sie mit uns den nächsten Schritt auf Ihrem ganz persönlichen Karriereweg. Mit mehr als 13.000 Mitarbeiterinnen und Mitarbeitern und rund 3 Milliarden Pfund Umsatz ist Computacenter der führende herstellerübergreifende Dienstleister für Informationstechnologie in Europa. Seit mehr als 30 Jahren entwickeln, implementieren und betreiben wir für unsere Kunden – ob Mittelstand oder DAX-Konzern - maßgeschneiderte IT-Lösungen. Damit wir unseren Weg erfolgreich weitergehen können, suchen wir Sie als

Technologie-Experte w/m – Office-Netzwerke WLAN Cisco CCIE oder CCNP Wireless, Industrie 4.0

ab sofort in München

Was Sie für uns tun können

Intensive Kundenkontakte, anspruchsvolle technologische Projektaufgaben und beste Rahmenbedingungen – das sind die Eckdaten einer Position, die wie gemacht ist für einen IT-Profi wie Sie. In Ihrer neuen Rolle entwickeln Sie anspruchsvolle Lösungskonzepte für neue Kundenanforderungen und setzen diese eigenständig um.

Was Sie dafür mitbringen sollten

Fundierte Fachkenntnisse und ausgiebige Projekterfahrung in komplexen IT-Umgebungen sind unverzichtbar für diese Position. Dabei spielt es für uns keine große Rolle, ob Sie Ihr Wissen und Können nach einem Hochschulstudium oder einer vergleichbaren Ausbildung durch Berufspraxis oder im Rahmen eines Trainings bei Computacenter erworben haben. Wichtiger ist uns, dass Sie sich stets aufs Neue von technologischen Innovationen begeistern lassen. Und dass Sie diese Faszination auch auf andere übertragen können. Deshalb sollten Sie Freude am Austausch mit anderen Menschen in deutscher wie auch in englischer Sprache haben. Wenn Sie außerdem noch spezielle Systemkenntnisse mitbringen und im Eskalations-, Konflikt- oder Qualitätsmanagement Bescheid wissen – umso besser!

Sie sind Spezialist im Bereich der Office-Netzwerke mit Schwerpunkt Wireless LAN (WLAN), die die Basis jeglicher Unternehmenskommunikation bilden. Diese Netzwerke müssen die Mobilität von Anwendern und die Flexibilität der Geschäftsprozesse unterstützen. Hierzu sorgen Sie für optimalen, drahtlosen Netzzugang und eine zeitgemäße Arbeitsplatzintegration. Ihr Know-how bildet die Grundlage zur Realisierung unserer Kundenprojekte in den Bereichen:

- Flexibler Benutzerzugang über Wireless LAN
- Sichere Integration mobiler Geräte wie Notebooks, Tablets und Smartphones
- Übergreifendes Netzwerkmanagement dieser Devices
- Durchführen von Site-Surveys
- Sehr gute Deutsch- und Englischkenntnisse in Wort und Schrift

Was wir Ihnen bieten

Bei Computacenter erwartet Sie eine kollegiale Teamatmosphäre, in der Sie sich mit Ihren persönlichen Stärken einbringen können. Unsere Größe ermöglicht es uns, Ihnen ein professionelles Arbeitsumfeld mit hoher Flexibilität für Ihre persönliche Lebensplanung zur Verfügung zu stellen. Darüber hinaus bieten wir Ihnen je nach Lebenslage eine Vielzahl an Zusatzleistungen, von der Aktienoption über zahlreiche Angebote durch unseren Familienservice. Und mit individuellen Entwicklungsmaßnahmen unterstützen wir Sie auf Ihrem ganz persönlichen Karriereweg bei uns.

Wir freuen uns auf Ihre Online-Bewerbung inklusive Motivationsschreiben, aussagekräftigem Lebenslauf und letzten Arbeitszeugnissen! Ihre Bewerbung richten Sie gerne auf Frau Anja Kossmann. Entspricht die ausgeschriebene Position nicht Ihrem Profil? Dann besuchen Sie uns auf dem Karriereportal von Computacenter – bei uns gibt es mehr als nur einen Weg für Sie!

Hier bewerben | Weiterempfehlen

Computacenter
Enabling Users

Figure 70: Example Job Offer, Retrieved from Monster Worldwide, Stored as HTML File, German Language

Appendix D: Source Code SAP HANA

D.1 Text Analysis: Configuration, Custom Dictionaries, Customer Extraction Rules (with regards to Hagn (2017))

D.1.1 Configuration file (EXTRACTION_CORE_EXTENDED.hdbtextconfig)

```
<?xml version="1.0" encoding="utf-8" ?>
<!-- Standard text analysis configuration for comprehensive linguistic analysis
     plus basic entity extraction (core entities only).
-->
<tasdk-configuration xmlns="http://www.sap.com/ta/config/4.0">

  <configuration name="SAP.TextAnalysis.AnalysisModel.AggregateAnalyzer.Aggregator">

    <!-- Specify sequence of text analysis steps to perform.

         Generally speaking, the only change that customers should make to this
         list is to include or exclude the 'ExtractionAnalyzer' step.
    -->
    <property name="Analyzers" type="string-list">
      <string-list-value>SAP.TextAnalysis.DocumentAnalysis.FormatConversion.FormatConversio-
nAnalyzer.FC</string-list-value>
      <string-list-value>SAP.TextAnalysis.DocumentAnalysis.StructureAnalysis.StructureAnaly-
zer.SA</string-list-value>
      <string-list-value>SAP.TextAnalysis.DocumentAnalysis.LinguisticAnalysis.LinguisticAnaly-
zer.LX</string-list-value>
      <string-list-value>SAP.TextAnalysis.DocumentAnalysis.Extraction.ExtractionAnaly-
zer.TF</string-list-value>
    </property>

  </configuration>

  <!-- Do not modify or remove. This section must appear exactly as described in the
       HANA Developer Guide.
  -->
  <configuration name="CommonSettings" />

  <!-- Do not modify or remove. This section must appear exactly as described in the
       HANA Developer Guide.
  -->
  <configuration name="SAP.TextAnalysis.DocumentAnalysis.FormatConversion.FormatConversionAna-
lyzer.FC" based-on="CommonSettings" />

  <!-- Do not remove. This section must be present as described in the HANA Developer Guide. -
->
  <configuration name="SAP.TextAnalysis.DocumentAnalysis.StructureAnalysis.StructureAnaly-
zer.SA" based-on="CommonSettings">

    <!-- Minimum input length (in code units) for which automatic language identification
         will be attempted. (The default language will be assigned to shorter inputs.)
    -->
    <property name="MinimumInputLength" type="integer">
      <integer-value>30</integer-value>
    </property>

    <!-- Size (in code units) of the input sample used for language identification. -->
    <property name="EvaluationSampleSize" type="integer">
        <integer-value>300</integer-value>
    </property>

    <!-- Minimum confidence level required to accept the result of automatic language
         detection. (Failing that, the default language will be used.)
         Values must be in the range from 0 to 100.
    -->
    <property name="MinimumConfidence" type="integer">
        <integer-value>50</integer-value>
    </property>
```

```
  </configuration>

  <!-- Do not remove. This section must be present as described in the HANA Developer Guide. -
->
  <configuration name="SAP.TextAnalysis.DocumentAnalysis.LinguisticAnalysis.LinguisticAnaly-
zer.LX" based-on="CommonSettings">

    <!-- Determine the stems (base forms) for each token?  (default is 'true') -->
    <property name="GetTokenStem" type="boolean">
      <boolean-value>true</boolean-value>
    </property>

    <!-- Guess stems for tokens not found in a lexicon?  (default is 'false') -->
    <property name="EnableStemGuesser" type="boolean">
      <boolean-value>false</boolean-value>
    </property>

    <!-- Determine the part of speech for each token?  (default is 'true') -->
    <property name="GetTokenPartOfSpeech" type="boolean">
      <boolean-value>true</boolean-value>
    </property>

    <!-- Disambiguate the part of speech for each token? (default is 'true') -->
    <property name="DisambiguatePartOfSpeech" type="boolean">
      <boolean-value>true</boolean-value>
    </property>

    <!-- Disambiguate the stem for each token? (default is 'false') -->
    <property name="DisambiguateStem" type="boolean">
      <boolean-value>true</boolean-value>
    </property>

    <!-- Use custom linguistic dictionaries?  (default is 'false') -->
    <property name="EnableCustomDictionaries" type="boolean">
      <boolean-value>true</boolean-value>
    </property>

    <!-- Determine whether stemming flavor is standard or expanded? (default is 'std') -->
    <property name="VariantString" type="string">
      <string-value>expanded</string-value>
    </property>

  </configuration>

  <!-- Configuration settings for entity and relationship extraction. Refer to the
      HANA Developer Guide for more details.
  -->
  <configuration name="SAP.TextAnalysis.DocumentAnalysis.Extraction.ExtractionAnalyzer.TF" ba-
sed-on="CommonSettings">

    <!-- List of repository objects containing Text Analysis extraction dictionaries. -->
    <!-- (Uncomment the following 'property' element to enable.) -->
    <property name="Dictionaries" type="string-list">
        <string-list-value>sap.hana.ta.dict::EDUCATION.hdbtextdict</string-list-value>
        <string-list-value>sap.hana.ta.dict::FIELDS_OF_STUDY.hdbtextdict</string-list-value>
        <string-list-value>sap.hana.ta.dict::COMPETENCIES.hdbtextdict</string-list-value>
        <string-list-value>sap.hana.ta.dict::EXPERIENCES.hdbtextdict</string-list-value>
    </property>
   <property name="ExtractionRules" type="string-list">
        <string-list-value>sap.hana.ta.dict::COMPETENCIES.hdbtextrule</string-list-value>
        <string-list-value>sap.hana.ta.dict::EXPERIENCES.hdbtextrule</string-list-value>
    </property>

  </configuration>

</tasdk-configuration>
```

D.1.2 Custom Dictionary for Competencies (COMPETENCIES.hdbtextdict)

```
<?xml version="1.0" encoding="UTF-8"?>
<dictionary
    xmlns="http://www.sap.com/ta/4.0" case-sensitive="false">
    <!-- 1.Leading & Deciding -->
    <entity_category name="COMP_1_1@Entscheidungsfaehigkeit">
        <entity_name standard_form="Entscheidungsfähigkeit">
```

```
        <variant name="Entscheidungsfähigkeiten" />
        <variant name="Entscheidungsfreude" />
        <variant name="Entscheidungsstärke" />
        <variant name="Entscheidungskompetenz" />
        <variant name="Entscheidungsfreudigkeit" />
    </entity_name>
</entity_category>
<entity_category name="COMP_1_1@Verantwortungsbewusstsein">
    <entity_name standard_form="Verantwortungsbewusstsein">
        <variant name="Verantwortungsbereitschaft" />
        <variant name="Folgebewusstsein" />
        <variant name="Pflichtgefühl" />
        <variant name="Pflichtbewusstsein" />
    </entity_name>
</entity_category>
<entity_category name="COMP_1_1@Selbstbewusstsein">
    <entity_name standard_form="Selbstbewusstsein">
        <variant name="Auftreten" />
        <variant name="Selbstsicherheit" />
    </entity_name>
</entity_category>
<entity_category name="COMP_1_1@Initiative">
    <entity_name standard_form="Initiative">
        <variant name="Eigeninitiative" />
    </entity_name>
</entity_category>
<entity_category name="COMP_1_1@Konsequenz">
    <entity_name standard_form="Konsequenz">
        <variant name="Entschlossenheit" />
    </entity_name>
</entity_category>
<entity_category name="COMP_1_1@Tatkraft">
    <entity_name standard_form="Tatkraft">
        <variant name="Elan" />
        <variant name="Dynamik" />
        <variant name="Hands-on-Mentalität" />
        <variant name="pragmatisch" />
        <variant name="Umsetzungsvermögen" />
        <variant name="Umsetzungskraft" />
        <variant name="Umsetzungsstärke" />
    </entity_name>
</entity_category>
<entity_category name="COMP_1_2@Fuehrungskompetenz">
    <entity_name standard_form="Führungskompetenz">
        <variant name="Führungsfähigkeiten" />
        <variant name="Führungseigenschaften" />
        <variant name="Führungspersönlichkeit" />
        <variant name="Führungsperson" />
        <variant name="Führungsstärke" />
        <variant name="Führungspotenzial" />
        <variant name="Führungsanspruch" />
        <variant name="Autorität" />
        <variant name="Führungserfahrung" />
        <variant name="Managementerfahrung" />
        <variant name="Teamleitungserfahrung" />
    </entity_name>
</entity_category>
<!-- 2.Supporting & Cooperating -->
<entity_category name="COMP_2_1">
    <entity_name standard_form="Sozialkompetenz">
        <variant name="soziale Kompetenz" />
        <variant name="Social Skills" />
    </entity_name>
</entity_category>
<entity_category name="COMP_2_1@Teamfaehigkeit">
    <entity_name standard_form="Teamfähigkeit">
        <variant name="Team-fähigkeit" />
        <variant name="Teamgeist" />
        <variant name="Team-Spirit" />
        <variant name="Teamorientierung" />
        <variant name="Teamplayer" />
        <variant name="Teamarbeit" />
        <variant name="Teambewusstsein" />
        <variant name="Integrationsfähigkeit" />
    </entity_name>
```

```xml
</entity_category>
<entity_category name="COMP_2_1@Kooperationsfaehigkeit">
    <entity_name standard_form="Kooperationsfähigkeit">
        <variant name="Kooperationsvermögen" />
        <variant name="Hilfsbereitschaft" />
        <variant name="Entgegenkommen" />
    </entity_name>
</entity_category>
<entity_category name="COMP_2_1@Kommunikationsfaehigkeit">
    <entity_name standard_form="Kommunikationsfähigkeit">
        <variant name="Kommunikationsfähigkeiten" />
        <variant name="Kommunikationsbereitschaft" />
        <variant name="Kommunikationskompetenz" />
        <variant name="Kommunikationstalent" />
        <variant name="Kommunikationsstärke" />
        <variant name="Kommunikationsfähigkeiten" />
        <variant name="Kommunikationsgeschick" />
        <variant name="Kommunikationssicherheit" />
        <variant name="kommunikationsstarker" />
        <variant name="kommunikationsstark" />
    </entity_name>
</entity_category>
<entity_category name="COMP_2_2@Integritaet">
    <entity_name standard_form="Integrität">
        <variant name="Vertrauenswürdigkeit" />
        <variant name="vertrauenswürdig" />
    </entity_name>
</entity_category>
<entity_category name="COMP_2_2@Loyalitaet">
    <entity_name standard_form="Loyalität"></entity_name>
</entity_category>
<!--im sinne von Werten, ethische Grundhaltung-->
<entity_category name="COMP_2_2@Normativ-ethische Einstellung">
    <entity_name standard_form="Normativ-ethische Einstellung">
        <variant name="ehrlich" />
    </entity_name>
</entity_category>
<entity_category name="COMP_2_2@Umweltbewusstsein">
    <entity_name standard_form="Umweltbewusstsein"></entity_name>
</entity_category>
<entity_category name="COMP_2_2@Ergonomiebewusstsein">
    <entity_name standard_form="Ergonomiebewusstsein"></entity_name>
</entity_category>
<entity_category name="COMP_2_2@Soziales Engagement">
    <entity_name standard_form="Soziales Engagement"></entity_name>
</entity_category>
<!-- 3.Interacting & Presenting -->
<entity_category name="COMP_3_1@Kompromissfaehigkeit">
    <entity_name standard_form="Kompromissfähigkeit"></entity_name>
</entity_category>
<entity_category name="COMP_3_1@Beziehungsmanagement">
    <entity_name standard_form="Beziehungsmanagement">
        <variant name="Schnittstellenkompetenz" />
        <variant name="Schnittstellenkompetenzen" />
        <variant name="Interaktionsfähigkeit" />
        <variant name="Kontaktfreudigkeit" />
    </entity_name>
</entity_category>
<entity_category name="COMP_3_1@Konfliktloesungsfaehigkeit">
    <entity_name standard_form="Konfliktlösungsfähigkeit">
        <variant name="Konfliktfähigkeit" />
        <variant name="Konfliktlösungsfähigkeiten" />
        <variant name="Konfliktmanagement" />
        <variant name="Eskalationsmanagement" />
        <variant name="Mediation" />
    </entity_name>
</entity_category>
<entity_category name="COMP_3_2@Verhandlungsgeschick">
    <entity_name standard_form="Verhandlungsgeschick">
        <variant name="Verhandlungsstärke" />
        <variant name="diplomatisches Geschick" />
        <variant name="Gesprächsführungskompetenz" />
    </entity_name>
</entity_category>
<entity_category name="COMP_3_2@Emotionale_Intelligenz">
    <entity_name standard_form="Emotionale Intelligenz">
```

```
        <variant name="Empathie" />
        <variant name="Einfühlungsvermögen" />
    </entity_name>
</entity_category>
<entity_category name="COMP_3_2@Impulsgeben">
    <entity_name standard_form="Impulsgeben">
        <variant name="Motivationsfähigkeit" />
        <variant name="Motivationsfähigkeiten" />
        <variant name="Motivationstalent" />
    </entity_name>
</entity_category>
<entity_category name="COMP_3_2@Schlagfertigkeit">
    <entity_name standard_form="Schlagfertigkeit">
        <variant name="Wortgewandtheit" />
        <variant name="Eloquenz" />
    </entity_name>
</entity_category>
<entity_category name="COMP_3_2@Akquisestaerke">
    <entity_name standard_form="Akquisestärke">
        <variant name="Akquise" />
        <variant name="Vertriebspersönlichkeit" />
        <variant name="Vertriebsaffinität" />
        <variant name="Abschlussstärke" />
        <variant name="Vertriebserfahrung" />
        <variant name="Vertriebs-Verständnis" />
    </entity_name>
</entity_category>
<entity_category name="COMP_3_2@Beratungsfaehigkeit">
    <entity_name standard_form="Beratungsfähigkeit">
        <variant name="Beratungsfähigkeiten" />
        <variant name="Beratungskompetenz" />
        <variant name="Beraterpersönlichkeit" />
        <variant name="Beraterqualitäten" />
        <variant name="Beratungserfahrung" />
    </entity_name>
</entity_category>
<entity_category name="COMP_3_2@Durchsetzungsfaehigkeit">
    <entity_name standard_form="Durchsetzungsfähigkeit">
        <variant name="Durchsetzungskraft" />
        <variant name="Durchsetzungsstärke" />
        <variant name="Durchsetzungsvermögen" />
        <variant name="Überzeugungsvermögen" />
        <variant name="Überzeugungskraft" />
        <variant name="Überzeugungsfähigkeit" />
    </entity_name>
</entity_category>
<entity_category name="COMP_3_3@Praesentationsfaehigkeit">
    <entity_name standard_form="Präsentationsfähigkeit">
        <variant name="Präsentation" />
        <variant name="Präsentationsfähigkeiten" />
        <variant name="Präsentationskompetenz" />
        <variant name="Präsentationssicherheit" />
        <variant name="Präsentationstechniken" />
        <variant name="Präsentationsstärke" />
        <variant name="Präsentationserfahrung" />
        <variant name="Visualisierungssicherheit" />
    </entity_name>
</entity_category>
<entity_category name="COMP_3_3@Sprachgewandtheit">
    <entity_name standard_form="Sprachgewandtheit">
        <variant name="rhetorische Fähigkeiten" />
        <variant name="rhetorische Gewandtheit" />
        <variant name="Ausdrucksfähigkeit" />
        <variant name="Ausdrucksvermögen" />
        <variant name="Sprachgefühl" />
        <!--Sprachkenntnisse werden mit Extraktionsregeln erfasst: COMP_3_3@Sprache-->
    </entity_name>
</entity_category>
<entity_category name="COMP_3_3@Moderationsfaehigkeit">
    <entity_name standard_form="Moderationsfähigkeit">
        <variant name="Moderation" />
        <variant name="Moderationsfähigkeiten" />
        <variant name="Moderationskenntnisse" />
        <variant name="Moderationstechniken" />
        <variant name="Moderationssicherheit" />
```

```
        <variant name="Moderationsskills" />
        <variant name="Moderationsstärke" />
        <variant name="Moderationserfahrung" />
    </entity_name>
</entity_category>
<!-- 4. Analyzing & Interpreting -->
<entity_category name="COMP_4_1@Lese-/Schreibkompetenz">
    <entity_name standard_form="Lese-/Schreibkompetenz">
        <variant name="Lesekompetenz" />
        <variant name="Schreibkompetenz" />
        <variant name="Textkompetenz" />
        <variant name="Textsicherheit" />
        <variant name="Rechtsschreibsicherheit" />
    </entity_name>
</entity_category>
<entity_category name="COMP_4_1@Zielgerichtete/technische_Kommunikation">
    <entity_name standard_form="Zielgerichtete/technische Kommunikation">
        <variant name="Zielgerichtete Kommunikation" />
        <variant name="technische Kommunikation" />
        <variant name="verständlich" />
        <variant name="zielgruppengerechte" />
    </entity_name>
</entity_category>
<!-- Fachwissen -->
<entity_category name="COMP_4_3@Problemloesungsfaehigkeit">
    <entity_name standard_form="Problemlösungsfähigkeit">
        <variant name="Problemlösefähigkeit" />
        <variant name="Problemlösungsfähigkeiten" />
        <variant name="Problemlösungskompetenz" />
        <variant name="Problemlösung" />
        <variant name="Problemlösungsverständnis" />
        <variant name="Problemlösungsorientierung" />
        <variant name="Lösungsorientierung" />
        <variant name="Lösungskompetenz" />
    </entity_name>
</entity_category>
<entity_category name="COMP_4_3@Optimierungskompetenz">
    <entity_name standard_form="Optimierungskompetenz">
        <variant name="Optimierung" />
    </entity_name>
</entity_category>
<entity_category name="COMP_4_3@Analytische_Faehigkeiten">
    <entity_name standard_form="Analytische Fähigkeiten">
        <variant name="Analysefähigkeit" />
    </entity_name>
</entity_category>
<entity_category name="COMP_4_3@Kognitive_Faehigkeiten">
    <entity_name standard_form="Kognitive Fähigkeiten">
        <variant name="Konzentration" />
        <variant name="Konzentrationsfähigkeit" />
        <variant name="Auffassungsgabe" />
        <variant name="Auffassungsvermögen" />
    </entity_name>
</entity_category>
<entity_category name="COMP_4_3@Sachlichkeit">
    <entity_name standard_form="Sachlichkeit">
        <variant name="Rationalität" />
    </entity_name>
</entity_category>
<!-- 5.Creating & Conceptualizing -->
<entity_category name="COMP_5_1@Lebenslanges_Lernen">
    <entity_name standard_form="Lebenslanges Lernen">
        <variant name="wissbegierig" />
        <variant name="Lernbereitschaft" />
        <variant name="Lernfreude" />
        <variant name="Lernwille" />
    </entity_name>
</entity_category>
<entity_category name="COMP_5_1@Wissensmanagement">
    <entity_name standard_form="Wissensmanagement"></entity_name>
</entity_category>
<entity_category name="COMP_5_2@Innovationsfreudigkeit">
    <entity_name standard_form="Innovationsfreudigkeit">
        <variant name="Innovationsfreude" />
        <variant name="Innovationsfähigkeit" />
        <variant name="Innovationsaffinität" />
```

```
        </entity_name>
    </entity_category>
    <entity_category name="COMP_5_2@Kreativitaet">
        <entity_name standard_form="Kreativität">
            <variant name="Schöpferische Fähigkeit" />
            <variant name="Einfallsreichtum" />
            <variant name="Erfindungsgabe" />
            <variant name="Improvisation" />
            <variant name="Improvisationsgeschick" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_5_2@Kritisches_Denken">
        <entity_name standard_form="Kritisches Denken">
            <variant name="Beurteilungsvermögen" />
            <variant name="Urteilskraft" />
            <variant name="Urteilsvermögen" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_5_2@Change_Management">
        <entity_name standard_form="Change Management">
            <variant name="Änderungswesen" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_5_2@Gestaltungswille">
        <entity_name standard_form="Gestaltungswille">
            <variant name="Gestaltungskraft" />
            <variant name="Gestaltungsmotivation" />
            <variant name="Gestaltungspersönlichkeit" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_5_3@Ganzheitliches_Denken">
        <entity_name standard_form="Ganzheitliches Denken"></entity_name>
    </entity_category>
    <entity_category name="COMP_5_3@Systematisch_methodisches_Vorgehen">
        <entity_name standard_form="Systematisch-methodisches Vorgehen"></entity_name>
    </entity_category>
    <entity_category name="COMP_5_3@Konzeptionsstaerke">
        <entity_name standard_form="Konzeptionsstärke">
            <variant name="konzeptionelles Denken" />
            <variant name="konzeptionelle Fähigkeit" />
            <variant name="konzeptionelle Fähigkeiten" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_5_3@Geschaeftsstrategie">
        <entity_name standard_form="Geschäftsstrategie"></entity_name>
    </entity_category>
    <entity_category name="COMP_5_3@Abstraktionsvermoegen">
        <entity_name standard_form="Abstraktionsvermögen">
            <variant name="Abstraktionsverhältnis" />
            <variant name="Abstraktion" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_5_3@Handhabung von Komplexitaet">
        <entity_name standard_form="Handhabung von Komplexität">
            <variant name="komplexe Sachverhalte" />
            <variant name="komplexe Zusammenhänge" />
            <variant name="komplexe Aufgabenstellungen" />
        </entity_name>
    </entity_category>
    <!-- 6.Organizing & Executing -->
    <entity_category name="COMP_6_1@Projektmanagement">
        <entity_name standard_form="Projektmanagement">
            <variant name="Projektleitungspraxis" />
            <variant name="Terminmanagement" />
            <variant name="Projektmanagementerfahrung" />
            <variant name="Projektmanagementerfahrungen" />
            <variant name="Projektleitungserfahrung" />
            <variant name="Projektleitungserfahrungen" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_6_1@Organisationsfaehigkeit">
        <entity_name standard_form="Organisationsfähigkeit">
            <variant name="Organisationsstärke" />
            <variant name="Organisationsvermögen" />
            <variant name="Organisationstalent" />
```

```
        <variant name="Organisationsgeschick" />
        <variant name="Koordinationsfähigkeit" />
        <variant name="Koordinationsfähigkeiten" />
        <variant name="Koordinationsstärke" />
        <variant name="Koordinationstalent" />
        <variant name="Koordinationsvermögen" />
        <variant name="Koordinationserfahrung" />
    </entity_name>
</entity_category>
<entity_category name="COMP_6_1@Planungsverhalten">
    <entity_name standard_form="Planungsverhalten">
        <variant name="Planungsfähigkeit" />
        <variant name="Planungsfähigkeiten" />
        <variant name="Strukturierungsvermögen" />
    </entity_name>
</entity_category>
<entity_category name="COMP_6_2@Kundenorientierung">
    <entity_name standard_form="Kundenorientierung">
        <variant name="kundenorientiert" />
        <variant name="Klientenorientierung" />
    </entity_name>
</entity_category>
<entity_category name="COMP_6_2@Kundenbeziehungsmanagement">
    <entity_name standard_form="Kundenbeziehungsmanagement">
        <variant name="Kundenbeziehung" />
        <variant name="Kundenbeziehungen" />
    </entity_name>
</entity_category>
<entity_category name="COMP_6_2@Projektarbeit">
    <entity_name standard_form="Projektarbeit">
        <variant name="Projekterfahrung" />
        <variant name="Projekterfahrungen" />
    </entity_name>
</entity_category>
<entity_category name="COMP_6_3@Ausfuehrungsbereitschaft">
    <entity_name standard_form="Ausführungsbereitschaft">
        <variant name="Motivation" />
        <variant name="Motiviertheit" />
        <variant name="Eigenmotivation" />
        <variant name="Selbstmotivation" />
    </entity_name>
</entity_category>
<entity_category name="COMP_6_3@Zuverlaessigkeit">
    <entity_name standard_form="Zuverlässigkeit"></entity_name>
</entity_category>
<entity_category name="COMP_6_3@Fleisz">
    <entity_name standard_form="Fleiß">
        <variant name="Eifer" />
        <variant name="Arbeitsfreude" />
        <variant name="Freude am Arbeiten" />
        <variant name="Begeisterungsfähigkeit" />
    </entity_name>
</entity_category>
<entity_category name="COMP_6_3@Disziplin">
    <entity_name standard_form="Disziplin">
        <variant name="Selbstkontrolle" />
        <variant name="Selbstbeherrschung" />
    </entity_name>
</entity_category>
<entity_category name="COMP_6_3@Gewissenhaftigkeit">
    <entity_name standard_form="Gewissenhaftigkeit">
        <variant name="Sorgfältigkeit" />
        <variant name="Qualitätsbewusstsein" />
        <variant name="qualitätsbewusste" />
        <variant name="Qualitätserfahrung" />
    </entity_name>
</entity_category>
<entity_category name="COMP_6_3@Bewusstsein_fuer_rechtliche_Fragen">
    <entity_name standard_form="Bewusstsein für rechtliche Fragen"></entity_name>
</entity_category>
<entity_category name="COMP_6_3@Sicherheitsbewusstsein">
    <entity_name standard_form="Sicherheitsbewusstsein">
        <variant name="Betriebssicherheit" />
        <variant name="Arbeitssicherheit" />
        <variant name="Ausfallsicherheit" />
    </entity_name>
```

```
    </entity_category>
    <entity_category name="COMP_6_3@Eigenverantwortung">
        <entity_name standard_form="Eigenverantwortung">
            <variant name="Eigenverantwortlichkeit" />
            <variant name="Eigenständigkeit" />
            <variant name="Eigenmächtigkeit" />
            <variant name="Selbstständigkeit" />
        </entity_name>
    </entity_category>
    <!-- 7.Adapting & Coping -->
    <entity_category name="COMP_7_1@Interdisziplinaeres_Arbeiten">
        <entity_name standard_form="Interdisziplinäres Arbeiten"></entity_name>
    </entity_category>
    <entity_category name="COMP_7_1@Interkulturelle_Kompetenz">
        <entity_name standard_form="Interkulturelle Kompetenz">
            <variant name="interkulturelle Kompetenzen" />
            <variant name="interkulturelle Skills" />
            <variant name="interkulturelles Verständnis" />
            <variant name="interkulturellen Zusammenarbeit" />
            <variant name="interkulturelle Zusammenarbeit" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_7_1@Flexibilitaet">
        <entity_name standard_form="Flexibilität">
            <variant name="Anpassungsfähigkeit" />
            <variant name="Spontanität" />
            <variant name="Mobilität" />
            <variant name="Reisebereitschaft" />
            <variant name="Reisetätigkeit" />
            <variant name="Entsendetätigkeit" />
            <variant name="Umzugsbereitschaft" />
            <variant name="Schichtarbeit" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_7_1@Offenheit_fuer_Veraenderungen">
        <entity_name standard_form="Offenheit für Veränderungen"></entity_name>
    </entity_category>
    <entity_category name="COMP_7_2@Work_Life_Balance">
        <entity_name standard_form="Work-Life Balance"></entity_name>
    </entity_category>
    <entity_category name="COMP_7_2@Belastbarkeit">
        <entity_name standard_form="Belastbarkeit">
            <variant name="Strapazierfähigkeit" />
            <variant name="Belastungsfähigkeit" />
            <variant name="Stressresistenz" />
            <variant name="Stresssituationen" />
            <variant name="Konfliktsituationen" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_7_2@Optimismus">
        <entity_name standard_form="Optimismus"></entity_name>
    </entity_category>
    <!-- 8.Enterprising & Performing -->
    <entity_category name="COMP_8_1@Selbst_Management">
        <entity_name standard_form="Selbst-Management">
            <variant name="Selbstmanagement" />
            <variant name="Zeitmanagement" />
            <variant name="Selbstorganisation" />
            <!--selbstorganisierte-->
        </entity_name>
    </entity_category>
    <entity_category name="COMP_8_1@Beharrlichkeit">
        <entity_name standard_form="Beharrlichkeit">
            <variant name="Hartnäckigkeit" />
            <variant name="Ausdauer" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_8_1@Einsatzbereitschaft">
        <entity_name standard_form="Einsatzbereitschaft">
            <variant name="Engagement" />
            <variant name="Hingabe" />
            <variant name="Leistungsbereitschaft" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_8_1@Ergebnisorientiertes_Handeln">
```

```
        <entity_name standard_form="Ergebnisorientiertes Handeln">
            <variant name="Ergebnisorientierung" />
            <variant name="Ergebnisorientiertheit" />
            <variant name="Zielorientierung" />
            <variant name="Zielorientiertheit" />
            <variant name="Zielstrebigkeit" />
            <variant name="Zielbewusstheit" />
            <variant name="Gewinnermentalität" />
            <variant name="Ehrgeiz" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_8_2@Geschaeftsmodellverstaendnis">
        <entity_name standard_form="Geschäftsmodellverständnis">
            <variant name="Geschäftsmodellentwicklung" />
            <variant name="Geschäftsmodelle" />
            <variant name="Geschäftsmodell" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_8_2@unternehmerisches_Denken">
        <entity_name standard_form="unternehmerisches Denken">
            <variant name="Unternehmergeist" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_8_2@Marktkenntnisse">
        <entity_name standard_form="Marktkenntnisse">
            <variant name="Branchen-Know-how" />
            <variant name="Branchenwissen" />
            <variant name="Fach-Know-how" />
            <variant name="Brancheneinblicke" />
            <variant name="Branchenerfahrung" />
            <variant name="Marktüberblick" />
        </entity_name>
    </entity_category>
    <!-- ########## Fachwissen ########## -->
    <!-- wie kann hier festgestellt werden ob es eine Anforderung ist????? -->
    <entity_category name="COMP_4_2@Technikaffinitaet">
        <entity_name standard_form="Technikaffinität">
            <!--Affinität zu technischen/technologischen .../ Affinität zu IT-... mit Regeln
erfassen -->
            <!--Affinität zu digitalen/technischen .../zu [..] IT / ... technischer Affinität-
->
            <variant name="Technik-Affinität" />
            <variant name="IT Affinität" />
            <variant name="IT-Affinität" />
            <variant name="technischer Affinität" />
            <variant name="Technikbegeisterung" />
            <variant name="technologisches Verständnis" />
            <variant name="technisches Grundverständnis" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_4_2@Wirtschaftliches_Verstaendnis">
        <entity_name standard_form="Wirtschaftliches Verständnis">
            <!--kaufmännisches Verständnis? -->
            <variant name="betriebswirtschaftliche Kenntnisse" />
            <variant name="BWL-Kenntnisse" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_4_2@Nutzenbringender_Einsatz_von_Social_Media">
        <entity_name standard_form="Nutzenbringender Einsatz von Social Media">
            <variant name="Social Media" />
            <variant name="sozialen Medien" />
            <variant name="sozialer Netzwerke" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_4_2@Fachuebergreifendes_Wissen">
        <entity_name standard_form="Fachübergreifendes Wissen">
            <variant name="interdisziplinäres Wissen" />
            <variant name="übergreifendes Wissen" />
            <variant name="fachübergreifendes Wissen" />
            <variant name="disziplinübergreifendes Wissen" />
            <variant name="bereichsübergreifendes Wissen" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_4_2@Lehrfaehigkeit">
        <entity_name standard_form="Lehrfähigkeit">
            <variant name="didaktisch" />
```

```
            <variant name="pädagogisch" />
            <variant name="unterrichtskundlich" />
        </entity_name>
    </entity_category>
    <!-- Fachwissen, das nur für bestimmte Bereiche notwendig ist -->
    <entity_category name="COMP_4_2@Dienstleistungsorientierung">
        <entity_name standard_form="Dienstleistungsorientierung">
            <variant name="Serviceorientierung" />
            <variant name="Service-Orientierung" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_4_2@Prozessmanagement">
        <entity_name standard_form="Prozessmanagement">
            <variant name="Prozessorientierung" />
            <variant name="Prozessverständnis" />
            <variant name="Prozessmanagementerfahrung" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_4_2@Business_Change_Management">
        <entity_name standard_form="Business Change Management"></entity_name>
    </entity_category>
    <entity_category name="COMP_4_2@Faehigkeit_Arbeitsablaeufe_zu_verstehen_koordinieren">
        <entity_name standard_form="Faehigkeit Arbeitsablaeufe zu verstehen/koordinieren">
            <variant name="Arbeitsabläufe" />
            <variant name="Arbeitsabläufen" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_4_2@Netzwerksicherheit">
        <entity_name standard_form="Netzwerksicherheit">
            <!-- <variant name="IT-Sicherheit" /><variant name="IT-security" /><variant
name="Security" />-->
        </entity_name>
    </entity_category>
    <entity_category name="COMP_4_2@IT_Architektur">
        <entity_name standard_form="IT Architektur">
            <variant name="IT-Architektur" />
            <variant name="IoT-Architektur" />
            <variant name="Enterprise-Architektur" />
            <variant name="Softwarearchitektur" />
            <variant name="Software-Architektur" />
            <variant name="Frontend-Architektur" />
            <variant name="Backend-Architektur" />
            <variant name="Systemarchitektur" />
            <variant name="Gesamtsystemarchitektur" />
            <variant name="Anwendungsarchitektur" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_4_2@Machine_Learning">
        <entity_name standard_form="Machine Learning">
            <variant name="Maschinelles Lernen" />
        </entity_name>
    </entity_category>
    <entity_category name="COMP_4_2@Systementwicklung">
        <entity_name standard_form="Systementwicklung">
            <!--nur Beschreibung der Stelle, keine Anforderung per se-->
        </entity_name>
    </entity_category>
    <entity_category name="COMP_4_2@Integration_verschiedener_Technologien">
        <entity_name standard_form="Integration verschiedener Technologien">
            <variant name="Systemintegration" />
            <!--<variant name="Integration" />-->
        </entity_name>
    </entity_category>
    <entity_category name="COMP_4_2@Mobile_Technologien">
        <entity_name standard_form="Mobile Technologien">
            <variant name="Mobile Technology" />
            <!--funkstandards, mobilfunk? -->
            <variant name="MQTT" />
            <variant name="RFID" />
            <variant name="Bluetooth" />
            <variant name="ZigBee" />
            <variant name="Wifi" />
            <variant name="3G" />
            <variant name="4G" />
            <variant name="5G" />
```

```
        <variant name="WLAN" />
    </entity_name>
</entity_category>
<entity_category name="COMP_4_2@Sensoren_Embedded_Systems">
    <entity_name standard_form="Sensoren/Embedded Systems">
        <variant name="Sensoren" />
        <variant name="Sensornetzwerke" />
        <variant name="Embededd Systems" />
        <variant name="Eingebettete Systeme" />
    </entity_name>
</entity_category>
<entity_category name="COMP_4_2@Netzwerktechnik_M2M_Kommunikation">
    <entity_name standard_form="Netzwerktechnik/M2M Kommunikation">
        <variant name="Netzwerktechnik" />
        <variant name="TCP/IP" />
        <variant name="Ethernet" />
        <variant name="EtherCat" />
        <variant name="M2M" />
        <variant name="Machine-to-Machine" />
    </entity_name>
</entity_category>
<entity_category name="COMP_4_2@Robotik_Künstliche_Intelligenz">
    <entity_name standard_form="Robotik/Künstliche Intelligenz">
        <variant name="Artifical Intelligence" />
        <variant name="Künstliche Intelligenz" />
        <variant name="Robotik" />
    </entity_name>
</entity_category>
<entity_category name="COMP_4_2@Predictive_Maintenance">
    <entity_name standard_form="Predictive Maintenance"></entity_name>
</entity_category>
<entity_category name="COMP_4_2@Modellierung_und_Programmierung">
    <entity_name standard_form="Modellierung und Programmierung">
        <!--mit rules verfeinern, weil sowas wie Kenntnisse in Programmierung fehlt-->
        <variant name="Programmiersprache" />
        <variant name="Programmiersprachen" />
        <variant name="Programmierkenntnisse" />
        <variant name="Programmiererfahrung" />
        <variant name="Entwicklungserfahrung" />
    </entity_name>
</entity_category>
<entity_category name="COMP_4_2@Big_Data_Datenanalyse_und_interpretation">
    <entity_name standard_form="Big Data/Datenanalyse und -interpretation">
        <variant name="Big Data" />
        <variant name="Data Analytics" />
    </entity_name>
</entity_category>
<entity_category name="COMP_4_2@Cloud_Computing_Architekturen">
    <entity_name standard_form="Cloud-Computing/-Architekturen">
        <variant name="Cloud-Computing" />
        <variant name="Cloud" />
        <variant name="IaaS" />
        <variant name="PaaS" />
        <variant name="SaaS" />
    </entity_name>
</entity_category>
<entity_category name="COMP_4_2@Statistik">
    <entity_name standard_form="Statistik">
        <variant name="statistische Methoden" />
    </entity_name>
</entity_category>
<entity_category name="COMP_4_2@Hauptspeicher_In_Memory_Datenbanken">
    <entity_name standard_form="Hauptspeicher-/In-Memory-Datenbanken">
        <variant name="In-Memory" />
        <variant name="In-Memory ?" />
        <variant name="Hauptspeicher" />
        <!--https://en.wikipedia.org/wiki/List_of_in-memory_databases -->
    </entity_name>
</entity_category>
<entity_category name="COMP_4_2@Datenschutz">
    <!--Datenschutz tritt nur als Datenschutzvermerk auf der Internetseite auf-->
    <entity_name standard_form="Datensicherheit">
        <variant name="Informationssicherheit" />
        <variant name="IT-Informationssicherheit" />
    </entity_name>
</entity_category>
```

```
</dictionary>
```

D.1.3 Custom Dictionary for Education (EDUCATION.hdbtextdict)

```
<?xml version="1.0" encoding="UTF-8"?>
<dictionary
    xmlns="http://www.sap.com/ta/4.0" case-sensitive="false">
    <entity_category name="EDUCATION">
        <entity_name standard_form="Hauptschulabschluss"></entity_name>
        <entity_name standard_form="Realschulabschluss">
            <variant name="Mittlere Reife" />
        </entity_name>
        <entity_name standard_form="Hochschulreife">
            <variant name="Abitur" />
            <variant name="Matura" />
        </entity_name>
        <entity_name standard_form="Ausbildung">
            <variant name="Berufsausbildung" />
        </entity_name>
        <entity_name standard_form="Meister"></entity_name>
        <entity_name standard_form="Immatrikulation">
            <variant name="Immatrikulationsbescheinigung" />
            <variant name="immatrikulierte" />
            <variant name="immatrikulierter" />
            <variant name="Sie studieren" />
            <variant name="Du studierst" />
            <variant name="Student" />
            <variant name="Student/in" />
        </entity_name>
        <entity_name standard_form="Abschlussarbeit">
            <variant name="Masterthesis" />
            <variant name="Bachelorthesis" />
            <variant name="Masterarbeit" />
            <variant name="Diplomarbeit" />
            <variant name="Bachelorarbeit" />
            <variant name="Thesis" />
        </entity_name>
        <entity_name standard_form="Studium">
            <variant name="(Hochschul)studium" />
            <variant name="Hochschulstudium" />
            <variant name="Hoch--schulstudium" />
            <variant name="Universitätsstudium" />
            <variant name="Bachelorstudium" />
            <variant name="Diplomstudium" />
            <variant name="Masterstudium" />
            <variant name="MBA" />
            <variant name="Akademische Ausbildung" />
            <variant name="Studiumabschluss" />
            <variant name="Abschluss eines Studiums" />
            <variant name="Studienabschluss" />
            <variant name="Hochschul-abschluss" />
            <variant name="Hochschul-absolvent" />
            <variant name="Absolvent" />
            <variant name="abgeschlossenes" />
        </entity_name>
        <entity_name standard_form="Promotionsstelle">
            <variant name="Möglichkeit ? Promotion" />
            <variant name="Promotionsmöglichkeit" />
        </entity_name>
        <!--doktorand, dr., doktor, postdoktorand-->
        <!-- Promotion nicht so einfach erkennbar, weil es meist eher eine Möglichkeit zur
Promotion ist -->
        <entity_name standard_form="PhD"></entity_name>
    </entity_category>
</dictionary>
```

D.1.4 Custom Dictionary for Experiences (EXPERIENCES.hdbtextdict)

```
<?xml version="1.0" encoding="UTF-8"?>
<dictionary
    xmlns="http://www.sap.com/ta/4.0" case-sensitive="false">
```

```
    <entity_category name="EXP@INTERNSHIP">
        <entity_name standard_form="Praktika">
            <variant name="Industriepraktika" />
        </entity_name>
    </entity_category>
    <entity_category name="EXP@INTERNATIONAL">
        <entity_name standard_form="Auslandserfahrung">
            <variant name="Auslandsaufenthalt" />
            <variant name="Auslandssemester" />
            <variant name="Internationale Erfahrung" />
        </entity_name>
    </entity_category>
    <entity_category name="EXP@WORK">
        <entity_name standard_form="Berufserfahrung">
            <variant name="Berufspraxis" />
            <variant name="Arbeitserfahrung" />
            <variant name="Firmenerfahrung" />
            <variant name="Praxiserfahrung" />
            <variant name="Industrieerfahrung" />
        </entity_name>
    </entity_category>
</dictionary>
```

D.1.5 Custom Dictionary for Study Subjects (FIELDS_OF_STUDY.hdbtextdict

```
<?xml version="1.0" encoding="UTF-8"?>
<dictionary
    xmlns="http://www.sap.com/ta/4.0" case-sensitive="true">
    <!-- 1.Geisteswissenschafen-->
    <!-- nur die allgemeine Benzeichnung wird übernommen, oft keine spezifischeren Angaben in
Anzeigen zu finden-->
    <entity_category name="STUDY@HUMAN_SCIENCE">
        <entity_name standard_form="Geisteswissenschaften">
            <variant name="Kommunikationswissenschaft" />
            <variant name="Kommunikationswissenschaften" />
            <variant name="Medienwissenschaft" />
        </entity_name>
    </entity_category>
    <!-- 3.Rechts-,Wirtschafts- und Sozialwissenschaften-->
    <entity_category name="STUDY@LAW_BUSINESS_SOCIAL">
        <entity_name standard_form="Rechts-, Wirtschafts- und Sozialwissenschaften">
            <variant name="Kommunikationswissenschaften" />
            <variant name="Kommunikationswissenschaft" />
            <variant name="Publizistik" />
        </entity_name>
        <entity_name standard_form="Regionalwissenschaften">
            <variant name="Ost- und Südosteuropa" />
            <variant name="Lateinamerika" />
            <variant name="Regionalwissenschaft" />
        </entity_name>
        <entity_name standard_form="Politikwissenschaften">
            <variant name="Politologie" />
            <variant name="Politikwissenschaft" />
        </entity_name>
        <entity_name standard_form="Sozialwissenschaften">
            <variant name="Sozialkunde" />
            <variant name="Sozialwissenschaft" />
            <variant name="Soziologie" />
        </entity_name>
        <entity_name standard_form="Sozialwesen">
            <variant name="Soziale Arbeit" />
            <variant name="Sozialpädagogik" />
            <variant name="Sozialwesen" />
        </entity_name>
        <entity_name standard_form="Rechtswissenschaften">
            <variant name="Jura" />
            <variant name="Rechtswissenschaft" />
            <variant name="Wirtschaftsrecht" />
        </entity_name>
        <entity_name standard_form="Verwaltungswissenschaften">
            <variant name="Archivwesen" />
            <variant name="Auswärtige Angelegenheiten " />
            <variant name="Bankwesen " />
            <variant name="Bibliothekswesen " />
            <variant name="Bundeswehrverwaltung " />
```

```
            <variant name="Finanzverwaltung " />
            <variant name="Innere Verwaltung " />
            <variant name="Justizvollzug " />
            <variant name="Polizei" />
            <variant name="Verfassungsschutz " />
            <variant name="Rechtspflege " />
            <variant name="Sozialversicherung " />
            <variant name="Verkehrswesen " />
            <variant name="Verwaltungswissenschaft" />
            <variant name="Verwaltungswesen " />
            <variant name="Zollverwaltung " />
            <variant name="Steuerverwaltung " />
        </entity_name>
        <entity_name standard_form="Wirtschaftswissenschaften">
            <variant name="Arbeitslehre" />
            <variant name="Wirtschaftslehre" />
            <variant name="Betriebswirtschaftslehre" />
            <variant name="Europäische Wirtschaft" />
            <variant name="Medienwirtschaft" />
            <variant name="Medienmanagement " />
            <variant name="Internationale Betriebswirtschaft" />
            <variant name="Internationales Management" />
            <variant name="Sportmanagement" />
            <variant name="Sportökonomie " />
            <variant name="Tourismuswirtschaft" />
            <variant name="Verkehrswirtschaft" />
            <variant name="Volkswirtschaftslehre" />
            <variant name="Wirtschaftspädagogik" />
        </entity_name>
        <entity_name standard_form="Wirtschaftsingenieurwesen mit wirtschaftswiss. Schwer-
punkt">
            <!-- aus Stellenanzeigen hinzugefügt -->
            <variant name="technisch-orientierte BWL" />
            <variant name="Facility Management" />
        </entity_name>
        <entity_name standard_form="Psychologie" />
        <entity_name standard_form="Erziehungswissenschaften">
            <variant name="Ausländerpädagogik" />
            <variant name="Wirtschaftspädagogik" />
            <variant name="Berufspädagogik" />
            <variant name="Erwachsenenbildung" />
            <variant name="Jugendbildung" />
            <variant name="Erziehungswissenschaft" />
            <variant name="Pädagogik der frühen Kindheit" />
            <variant name="Grundschulpädagogik" />
            <variant name="Primarstufenpädagogik" />
            <variant name="Sachunterricht" />
            <variant name="Schulpädagogik" />
            <variant name="Sonderpädagogik" />
        </entity_name>
    </entity_category>
    <!-- 4.Mathematik, Naturwissenschaften-->
    <entity_category name="STUDY@MATH_SCIENCE">
        <!--Hinzugefügt, allgemeine Bezeichnung -->
        <entity_name standard_form="Naturwissenschaften">
            <variant name="Naturwissenschaft" />
        </entity_name>
        <entity_name standard_form="Mathematik">
            <variant name="Mathematische Statistik" />
            <variant name="Wahrscheinlichkeitsrechnung" />
            <variant name="Technomathematik" />
            <variant name="Wirtschaftsmathematik" />
        </entity_name>
        <entity_name standard_form="Physik">
            <variant name="Astronomie" />
            <variant name="Astrophysik" />
            <!-- aus Stellenanzeigen hinzugefügt -->
            <variant name="Wirtschaftsphysik" />
        </entity_name>
        <entity_name standard_form="Chemie">
            <variant name="Biochemie" />
            <variant name="Lebensmittelchemie" />
        </entity_name>
        <entity_name standard_form="Pharmazie" />
        <entity_name standard_form="Biologie">
```

```xml
            <variant name="Anthropologie" />
            <variant name="Humanbiologie" />
            <variant name="Biomedizin" />
            <variant name="Biotechnologie" />
        </entity_name>
        <entity_name standard_form="Geowissenschaften">
            <variant name="Geologie" />
            <variant name="Paläontologie" />
            <variant name="Geophysik" />
            <variant name="Meteorologie" />
            <variant name="Mineralogie" />
            <variant name="Ozeanographie" />
        </entity_name>
        <entity_name standard_form="Geographie">
            <variant name="Erdkunde" />
            <variant name="Biogeographie" />
            <variant name="Wirtschaftsgeographie" />
            <variant name="Sozialgeographie" />
        </entity_name>
    </entity_category>
    <!--8.Ingenieurwissenschaften-->
    <entity_category name="STUDY@ENGINEERING">
        <!--Hinzugefügt, allgemeine Bezeichnung -->
        <entity_name standard_form="Ingenieurwissenschaften">
            <variant name="Wirtschaftsingenieurwesen" />
        </entity_name>
        <entity_name standard_form="Ingenieurwesen">
            <variant name="Angewandte Systemwissenschaften" />
            <variant name="Lernbereich Technik" />
            <variant name="Mechatronik" />
            <variant name="Medientechnik" />
            <variant name="Regenerative Energien" />
        </entity_name>
        <entity_name standard_form="Bergbau, Hüttenwesen ">
            <variant name="Archäometrie" />
            <variant name="Ingenieurarchäologie" />
            <variant name="Bergbau/Bergtechnik" />
            <variant name="Hüttenwesen" />
            <variant name="Gießereiwesen" />
            <variant name="Markscheidewesen" />
        </entity_name>
        <entity_name standard_form="Maschinenbau/Verfahrenstechnik">
            <variant name="Maschinenbau" />
            <variant name="Verfahrenstechnik" />
            <variant name="Abfallwirtschaft" />
            <variant name="Augenoptik" />
            <variant name="Chemie-Ingenieurwesen" />
            <variant name="Chemietechnik" />
            <variant name="Drucktechnik" />
            <variant name="Reproduktionstechnik" />
            <variant name="Energietechnik" />
            <variant name="Produktionstechnik" />
            <variant name="Fertigungstechnik" />
            <variant name="Holztechnik" />
            <variant name="Fasertechnik" />
            <variant name="Kerntechnik" />
            <variant name="Kernverfahrenstechnik" />
            <variant name="Kunststofftechnik" />
            <variant name="Maschinenwesen" />
            <variant name="Metalltechnik" />
            <variant name="Physikalische Technik" />
            <variant name="Technische Kybernetik" />
            <variant name="Textiltechnik" />
            <variant name="Textiltechnikgewerbe" />
            <variant name="Bekleidungsgewerbe" />
            <variant name="Bekleidungstechnik" />
            <variant name="Transporttechnik" />
            <variant name="Fördertechnik" />
            <variant name="Umwelttechnik" />
            <variant name="Verfahrenstechnik" />
            <variant name="Versorgungstechnik" />
        </entity_name>
        <entity_name standard_form="Automatisierungstechnik">
            <variant name="Robotik" />
        </entity_name>
        <entity_name standard_form="Elektrotechnik und Informationstechnik">
```

```
            <variant name="Elektrische Energietechnik" />
            <variant name="Elektrotechnik" />
            <variant name="Elektronik" />
            <variant name="Mikroelektronik" />
            <variant name="Mikrosystemtechnik" />
            <variant name="Kommunikationstechnik" />
            <variant name="Informationstechnik" />
            <variant name="Optoelektronik" />
            <!-- aus Stellenanzeigen hinzugefügt -->
            <variant name="Nachrichtentechnik" />
        </entity_name>
        <entity_name standard_form="Verkehrstechnik, Nautik">
            <variant name="Fahrzeugtechnik" />
            <variant name="Luft- und Raumfahrttechnik" />
            <variant name="Lufttechnik" />
            <variant name="Raumfahrttechnik" />
            <variant name="Nautik" />
            <variant name="Seefahrt" />
            <variant name="Schiffbau" />
            <variant name="Schiffstechnik" />
            <variant name="Verkehrsingenieurwesen" />
        </entity_name>
        <entity_name standard_form="Architektur, Innenarchitektur">
            <variant name="Architektur" />
            <variant name="Innenarchitektur" />
        </entity_name>
        <entity_name standard_form="Raumplanung">
            <variant name="Raumplanung" />
            <variant name="Umweltschutz" />
        </entity_name>
        <entity_name standard_form="Bauingenieurwesen">
            <variant name="Ingenieurbau" />
            <variant name="Holzbau" />
            <variant name="Wasserbau" />
            <variant name="Wasserwirtschaft" />
            <variant name="Stahlbau" />
        </entity_name>
        <entity_name standard_form="Vermessungswesen">
            <variant name="Geodäsie" />
            <variant name="Kartographie" />
        </entity_name>
        <entity_name standard_form="Informatik">
            <variant name="Bioinformatik" />
            <variant name="Computer- und Kommunikationstechnik" />
            <variant name="Informatik" />
            <variant name="Ingenieurinformatik" />
            <variant name="Technische Informatik" />
            <variant name="Medieninformatik" />
            <variant name="Medizinische Informatik" />
            <variant name="Wirtschaftsinformatik" />
        </entity_name>
        <entity_name standard_form="Materialwissenschaft und Werkstofftechnik">
            <variant name="Materialwissenschaften" />
            <variant name="Werkstofftechnik" />
        </entity_name>
    </entity_category>
</dictionary>
```

D.1.6 Custom Lexicon for Languages in German (languages-german.hdbtextlexicon)

```
Afrikaans
Albanisch
Amharisch
Arabisch
Armenisch
Aserbaidschanisch
Bengalisch
Bhutanisch
Birmanisch
Bislama
Bosnisch
Bulgarisch
Chichewa
```

Chinesisch
Dänisch
Dari
Deutsch
Englisch
Estnisch
Fidschianisch
Filipino
Tagalog
Finnisch
Französisch
Georgisch
Gilbertesisch
Griechisch
Guaraní
Haitianisch
Hebräisch
Hindi
Indonesisch
Irisch
Isländisch
Italienisch
Japanisch
Kambodschanisch
Kasachisch
Katalanisch
Kirgisisch
Kirundi
Koreanisch
Kroatisch
Kurdisch
Laotisch
Lateinisch
Lettisch
Litauisch
Madagassisch
Malaiisch
Maledivisch
Maltesisch
Maori
Marshallesisch
Mazedonisch
Mongolisch
Montenegrinisch
Nauruisch
Ndebele
Nepalesisch
Niederländisch
Nordsotho
Norwegisch
Palauisch
Paschtu
Persisch
Polnisch
Portugiesisch
Rätoromanisch
Rumänisch
Russisch
Samoanisch
Sango
Schwedisch
Serbisch
Singhalesisch
Slowakisch
Slowenisch
Somali
Sotho
Spanisch
Suaheli
Südsotho
Swasi
Tadschikisch
Tamilisch
Tetum
Thailändisch
Tigrinja

```
Neomelanesisch
Tongaisch
Tschechisch
Tsonga
Tsuana
Türkisch
Turkmenisch
Tuvalu
Tuvaluisch
Ukrainisch
Ungarisch
Urdu
Usbekisch
Venda
Vietnamesisch
Weißrussisch
Xhosa
Zulu
```

D.1.7 Custom Extraction Rule for Competencies (COMPETENCIES.hdbtextrule)

```
#lexicon LANGUAGE_LIST "sap.hana.ta.dict::languages-german.hdbtextlexicon"

! ###### subgroups ######
#subgroup ABILITY: {
<STEM: \p{ci} Arbeit|Arbeiten|Arbeitsweise|Arbeitsstil|Argumentation|Bearbeitung|Begabung|Den-
ken|Denkweise|Denkvermögen|
Erfahrung|Fähigkeit|Geschick|Handeln|Herangehensweise|Kenntnis|Kompetenz|Köpfe|Person|Persön-
lichkeit|Potenzial|Qualitäten|Sachverstand|Sachverständnis|
Skills|Stärke|Talent|Vermögen|Vorgehensweise>
}

#subgroup ACT_VERBS: {
<STEM: sein|agieren|arbeiten|führen|handeln|leiten|denken|verfolgen>
}

#subgroup KNOWLEDGE: {
<\p{ci} Begabung|Berufserfahrung|Erfahrung|Kenntnisse|Know-How|Know How|Umgang|Verständ-
nis|Wissen>
}

#subgroup ADJ_ENUM_BEFORE_NOUN: {
   (<\,><POS: Adj>)* (<POS: Conj> <POS: Adj>)? %(ABILITY)
}

#subgroup ADJ_ENUM_AFTER_VERB: {
   %(ACT_VERBS) (<POS: Adj><\,>)* (<POS: Adj><POS: Conj>)?
}

#subgroup NOMEN_ENUM_AFTER_NOUN: {
   ! war vorher: (<\,><.+\->)*<POS: Conj|Punct>
   (<\,|/><.+\->)*<POS: Conj|Punct>
}

! ###### Erweiterung der Kompetenzen ######
#subgroup ADJ_Entscheidungsfaehigkeit: <STEM: entscheidungsfreudig>
#group COMP_1_1@Entscheidungsfaehigkeit: {
   %(ADJ_Entscheidungsfaehigkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Entscheidungsfaehigkeit)
   | <Entscheidungen><treffen>
}

#subgroup ADJ_Verantwortungsbewusstsein: <STEM: verantwortungsbewusst|folgebewusst>
#group COMP_1_1@Verantwortungsbewusstsein: {
   %(ADJ_Verantwortungsbewusstsein) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Verantwortungsbewusstsein)
   | <POS: Pron-Pers><STEM: übernehmen><.+>?<Verantwortung>
   | <Übernahme><von><Verantwortung>
   | <Verantwortungs\->  %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}
```

```
#subgroup ADJ_Selbstbewusstsein: <STEM: selbstbewusst>
#group COMP_1_1@Selbstbewusstsein: {
    %(ADJ_Selbstbewusstsein) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Selbstbewusstsein)
}

#subgroup ADJ_Initiative: <STEM: initiativ|proaktiv|pro-aktiv|eigeninitiativ>
#group COMP_1_1@Initiative: {
   %(ADJ_Initiative) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Initiative)
}

#subgroup ADJ_Konsequenz: <STEM: konsequent|entschlossen>
#group COMP_1_1@Konsequenz: {
   %(ADJ_Konsequenz) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Konsequenz)
}

#subgroup ADJ_Tatkraft: <STEM: tatkräftig|dynamisch|pragmatisch|umsetzungsorientiert>
#group COMP_1_1@Tatkraft: {
   %(ADJ_Tatkraft) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Tatkraft)
   ! Umsetzungs-?
}

#group COMP_1_2@Fuehrungskompetenz: {
   <Führung> <von> <POS: Adj>* <STEM: Mitarbeitern|Team>
   | <Führungs\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Sozialkompetenz: <STEM: sozial>
#group COMP_2_1: {
   %(ADJ_Sozialkompetenz) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Sozialkompetenz)
}

#subgroup ADJ_Teamfaehigkeit: <STEM: teamfähig|teamorientiert>
#group COMP_2_1@Teamfaehigkeit: {
   %(ADJ_Teamfaehigkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Teamfaehigkeit)
}

#subgroup ADJ_Kooperationsfaehigkeit: <STEM: kooperativ|kooperationsfähig|hilfsbereit>|<koope-
rations.?>
#group COMP_2_1@Kooperationsfaehigkeit: {
   %(ADJ_Kooperationsfaehigkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Kooperationsfaehigkeit)
   | <Kooperations\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Kommunikationsfaehigkeit: <STEM: kommunikationsstark|kommunikativ|kommunikati-
onsfähig>
#group COMP_2_1@Kommunikationsfaehigkeit: {
   %(ADJ_Kommunikationsfaehigkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Kommunikationsfaehigkeit)
   | <Kommunikations\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Integritaet: <STEM: vertrauenswürdig|integer>
#group COMP_2_2@Integritaet: {
   %(ADJ_Integritaet) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Integritaet)
}

#subgroup ADJ_Kompromissfaehigkeit: <STEM: kompromissfähig>
#group COMP_3_1@Kompromissfaehigkeit: {
   %(ADJ_Kompromissfaehigkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Kompromissfaehigkeit)
}
```

```
#subgroup ADJ_Beziehungsmanagement: <STEM: kontaktfreudig>
#group COMP_3_1@Beziehungsmanagement: {
   %(ADJ_Beziehungsmanagement) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Beziehungsmanagement)
   | <Kontakt\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#group COMP_3_2@Konfliktloesungsfaehigkeit: {
   <Konflikt|Eskalation\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#group COMP_3_2@Verhandlungsgeschick: {
   <Verhandlungs\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Emotionale_Intelligenz: <STEM: empathisch>
#group COMP_3_2@Emotionale_Intelligenz: {
   %(ADJ_Emotionale_Intelligenz) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Emotionale_Intelligenz)
}

#subgroup ADJ_Akquisestaerke: <STEM: vertriebsstark>
#group COMP_3_2@Akquisestaerke: {
   %(ADJ_Akquisestaerke) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Akquisestaerke)
   | <Vertriebs\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#group COMP_3_2@Beratungsfaehigkeit: {
   <Beratungs\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Durchsetzungsfaehigkeit: <STEM: durchsetzungsfähig|durchsetzungsstark|überzeu-
gend>
#group COMP_3_2@Durchsetzungsfaehigkeit: {
   %(ADJ_Durchsetzungsfaehigkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Durchsetzungsfaehigkeit)
   | <Überzeugungs|Durchsetzungs\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#group COMP_3_3@Praesentationsfaehigkeit: {
   <Präsentations\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Sprachgewandtheit: <STEM: rhetorisch>
#group COMP_3_3@Sprachgewandtheit: {
   %(ADJ_Sprachgewandtheit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Sprachgewandtheit)
}

#group COMP_3_3@Moderationsfaehigkeit: {
   <Moderations\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

! Fachwissen
#group COMP_4_2@Wirtschaftliches_Verstaendnis: {
   (<STEM: betriebswirtschaftlich|wirtschaftliche> %(KNOWLEDGE))
}
```

```
#subgroup ADJ_Lehrfaehigkeit: <STEM: didaktisch|pädagogisch|unterrichtskundlich|lehrfähig>
#group COMP_4_2@Lehrfaehigkeit: {
   %(ADJ_Lehrfaehigkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Lehrfaehigkeit)
}

#subgroup ADJ_Dienstleistungsorientierung: <STEM: dienstleistungsorientiert|serviceorien-
tiert|service-orientiert|supportorientiert>
#group COMP_4_2@Dienstleistungsorientierung: {
   %(ADJ_Dienstleistungsorientierung) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Dienstleistungsorientierung)
   | <Service\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Prozessmanagement: <STEM: prozessorientiert>
#group COMP_4_2@Prozessmanagement: {
   %(ADJ_Prozessmanagement) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Prozessmanagement)
   | <Prozess\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

!#group COMP_4_2@Hauptspeicher_In_Memory_Datenbanken: {}

#group COMP_4_2@Statistik: {
   <STEM: statistisch, POS: Adj> <STEM: Analyse|Datenanalyse|Methode|Methoden|Modell|Simula-
tion>
}

! Fachwissen Ende

#subgroup ADJ_Problemloesungsfaehigkeit: <STEM: lösungsorientiert>
#group COMP_4_3@Problemloesungsfaehigkeit: {
   %(ADJ_Problemloesungsfaehigkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Problemloesungsfaehigkeit)
   | <Lösungs\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Analytische_Faehigkeiten: <STEM: analytisch|logisch>
#group COMP_4_3@Analytische_Faehigkeiten: {
   %(ADJ_Analytische_Faehigkeiten) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Analytische_Faehigkeiten)
   | <Analyse\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#group COMP_4_3@Kognitive_Faehigkeiten: {
   <Denk\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#group COMP_5_1@Lebenslanges_Lernen: {
   <Bereitschaft|Motivation> <.+>{0,2} <Qualifikation|Weiterbildung|Weiterentwicklung>
   | <Neues><zu><lernen>
   | <Lern\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Innovationsfreudigkeit: <STEM: innovativ>
#group COMP_5_2@Innovationsfreudigkeit: {
   %(ADJ_Innovationsfreudigkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Innovationsfreudigkeit)
   | <Innovations\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Kreativitaet: <STEM: einfallsreich|kreativ|pfiffig|unkonventionell>
```

```
#group COMP_5_2@Kreativitaet: {
   %(ADJ_Kreativitaet) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Kreativitaet)
}

#group COMP_5_2@Kritisches_Denken: {
   <STEM: hinterfragen>
   | <Urteils\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Ganzheitliches_Denken: <STEM: ganzheitlich|gesamtheitlich|holistisch>
#group COMP_5_3@Ganzheitliches_Denken: {
   %(ADJ_Ganzheitliches_Denken) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Ganzheitliches_Denken)
   | <Blick> <.+>{0,2} <Ganze>
}

#subgroup ADJ_Systematisch_methodisches_Vorgehen: <STEM: systematisch|methodisch>
#group COMP_5_3@Systematisch_methodisches_Vorgehen: {
   %(ADJ_Systematisch_methodisches_Vorgehen) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Systematisch_methodisches_Vorgehen)
   | <Methoden\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Konzeptionsstaerke: <STEM: konzeptionell>
#group COMP_5_3@Konzeptionsstaerke: {
   %(ADJ_Konzeptionsstaerke) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Konzeptionsstaerke)
}

#subgroup ADJ_Geschaeftsstrategie: <STEM: strategisch>
#group COMP_5_3@Geschaeftsstrategie: {
   %(ADJ_Geschaeftsstrategie) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Geschaeftsstrategie)
}

#subgroup ADJ_Abstraktionsvermoegen: <STEM: abstrakt>
#group COMP_5_3@Abstraktionsvermoegen: {
   %(ADJ_Abstraktionsvermoegen) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Abstraktionsvermoegen)
}

#subgroup ADJ_Projektmanagement: <STEM: projektorientiert>
#group COMP_6_1@Projektmanagement: {
   %(ADJ_Projektmanagement) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Projektmanagement)
   | <Projekt\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Organisationsfaehigkeit: <STEM: organisatorisch>
#group COMP_6_1@Organisationsfaehigkeit: {
   %(ADJ_Organisationsfaehigkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Organisationsfaehigkeit)
   | <Organisations|Koordinations\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Planungsverhalten: <STEM: planmäßig|planvoll|strukturiert>
#group COMP_6_1@Planungsverhalten: {
   %(ADJ_Planungsverhalten) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Planungsverhalten)
   | <Planungs\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#group ADJ_Kundenorientierung: <STEM: kundenorientiert|klientenorientiert|anwenderorientiert>
#group COMP_6_2@Kundenorientierung: {
```

```
   %(ADJ_Kundenorientierung) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Kundenorientierung)
   | <Kunden\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#group COMP_6_2@Projektarbeit: {
   <Projekt\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Motivation: <STEM: eigenmotiviert|motiviert>
#group COMP_6_3@Motivation: {
   %(ADJ_Motivation) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Motivation)
   | <Motivation\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Zuverlaessigkeit: <STEM: zuverlässig|verlässlich>
#group COMP_6_3@Zuverlaessigkeit: {
   %(ADJ_Zuverlaessigkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Zuverlaessigkeit)
}

#subgroup ADJ_Fleisz: <STEM: leidenschaftlich|fleißig>
#group COMP_6_3@Fleisz: {
   %(ADJ_Fleisz) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Fleisz)
   | <Begeisterungs\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Disziplin: <STEM: beherrscht|diszipliniert>
#group COMP_6_3@Disziplin: {
   %(ADJ_Disziplin) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Disziplin)
}

#subgroup ADJ_Gewissenhaftigkeit: <STEM: gewissenhaft|sorgfältig|qualitätsbewusst|gründ-
lich|ordentlich|präzise>
#group COMP_6_3@Gewissenhaftigkeit: {
   %(ADJ_Gewissenhaftigkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Gewissenhaftigkeit)
}

#group COMP_6_3@Bewusstsein_fuer_rechtliche_Fragen: {
   <STEM: rechtlich><POS: Nn>
}

#subgroup ADJ_Eigenverantwortung: <STEM: eigenverantwortlich|selbstverantwortlich|selbststän-
dig|eigenständig>
#group COMP_6_3@Eigenverantwortung: {
   %(ADJ_Eigenverantwortung) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Eigenverantwortung)
}

#subgroup ADJ_Interdisziplinaeres_Arbeiten: <STEM: interdisziplinär|übergreifend|abteilungs-
übergreifend|fachübergreifend|disziplinübergreifend|bereichsübergreifend|technologieübergrei-
fend>
#group COMP_7_1@Interdisziplinaeres_Arbeiten: {
   %(ADJ_Interdisziplinaeres_Arbeiten) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Interdisziplinaeres_Arbeiten)
}

#subgroup ADJ_Interkulturelle_Kompetenz: <STEM: interkulturell>
#group COMP_7_1@Interkulturelle_Kompetenz: {
   %(ADJ_Interkulturelle_Kompetenz) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Interkulturelle_Kompetenz)
}

#subgroup ADJ_Flexibilitaet: <STEM: flexibel|reisebereit>
```

```
#group COMP_7_1@Flexibilitaet: {
   %(ADJ_Flexibilitaet) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Flexibilitaet)
   | <Bereitschaft> <.+>{0,2} <POS: Adj>{0,1} <STEM: \p{ci} Dienstreisen|Business Trips|Aus-
landsaufenthalten|Reisen|Entsendetätigkeit|Reisetätigkeit>
   | <Reise\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Belastbarkeit: <STEM: stressresistent|belastbar>
#group COMP_7_2@Belastbarkeit: {
   %(ADJ_Belastbarkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Belastbarkeit)
}

#group COMP_8_1@Selbst_Management: {
   <Selbst|Zeit\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_Beharrlichkeit: <STEM: beharrlich|ausdauernd>
#group COMP_8_1@Beharrlichkeit: {
   %(ADJ_Beharrlichkeit) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Beharrlichkeit)
}

#subgroup ADJ_Einsatzbereitschaft: <STEM: engagiert>
#group COMP_8_1@Einsatzbereitschaft: {
   %(ADJ_Einsatzbereitschaft) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Einsatzbereitschaft)
}


#subgroup ADJ_Ergebnisorientiertes_Handeln: <STEM: ergebnisorientiert|zielorientiert|zielge-
richtet|zielstrebig>
#group COMP_8_1@Ergebnisorientiertes_Handeln: {
   %(ADJ_Ergebnisorientiertes_Handeln) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_Ergebnisorientiertes_Handeln)
   | <Ziel|Ergebnis\-> %(NOMEN_ENUM_AFTER_NOUN) [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#subgroup ADJ_unternehmerisches_Denken: <STEM: unternehmerisch>
#group COMP_8_2@unternehmerisches_Denken: {
   %(ADJ_unternehmerisches_Denken) %(ADJ_ENUM_BEFORE_NOUN)
   | %(ADJ_ENUM_AFTER_VERB) %(ADJ_unternehmerisches_Denken)
}

#group COMP_8_2@Marktkenntnisse: {
   (<STEM: Branche><POS: Punct> %(KNOWLEDGE))
}

! ################# Sprache ####################
! LANGUAGE ist vordefiniert, deshalb wird alternativ LANG verwendet
! Wörter mit denselben Stamm, groß und klein: auch "Deutsch-"
#subgroup LANG: <STEM: \p{ci} %(LANGUAGE_LIST)>

! COMP_3_3@Sprache_DESC
#group COMP_3_3@Sprache: {
   ! Englisch- und Deutschkenntnisse
   (%(LANG) <\,>)* (%(LANG) <POS: Conj>)? < %(LANGUAGE_LIST) kenntnisse>
   ! deutscher und englischer Sprache
   | %(LANG) (<\,> %(LANG))* (<POS: Conj> %(LANG))? <Sprache|Sprachkenntnisse|Kenntnisse>
   ! weitere Fremdsprache
   | <weiter(e|en)>? <Fremdsprache|Fremdsprachenkenntnisse>
   ! gutes Deutsch, verhandlungssicheres Englisch, usw.
   | <POS: Adj> (<%(LANGUAGE_LIST)><\,>)* (<%(LANGUAGE_LIST)><POS: Conj>)? <%(LANGUAGE_LIST)>
   ! in (fließendem) Deutsch und Englisch
   | <POS: Prep> <POS: Adj>* (<%(LANGUAGE_LIST)> <\,>)* (<%(LANGUAGE_LIST)><POS: Punct|Conj>)?
<%(LANGUAGE_LIST)>
}
```

```
! ######## Erfassung von Anforderungen aus Aufzählungen ############
#group COMP@ENUM: {
   ! z.B. Team- und Kommunikationsfähigkeit oder Integrations-- und Problemlösungsfähigkeit
   ([OD COMP@ENUM_PART]<.+\->[/OD]<\,>)* [OD COMP@ENUM_PART] <.+\-> [/OD] <POS: Conj|Punct>
[TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

! Studium wird über Dictionary gemacht, Verfeinerung dann per SQL in der Auswertung
#group STUDY@ENUM: {
   ! z.B. Ingenieurs-, Wirtschafts- oder Naturwissenschaften
   ([OD STUDY@ENUM_PART]<.+\->[/OD]<\,>)* [OD STUDY@ENUM_PART] <.+\-> [/OD] <POS: Conj|Punct>
[TE STUDY]<>+[/TE]
}
```

D.1.8 Custom Extraction Rule for Experiences (EXPERIENCES.hdbtextrule)

```
! ###### subgroups ######
#subgroup KNOWLEDGE: {
<\p{ci} Begabung|Berufserfahrung|Erfahrung|Kenntnisse|Know-How|Know How|Umgang|Verständ-
nis|Wissen>
}

! ###### groups ######
! was ist mit: praktische Erfahrungen, erste Erfahrungen, mehrjährige Erfahrung, fundierte Er-
fahrung
! Berufserfahrung
#group EXP@WORK: {
   <Berufs\-> (<\,><.+\->)* <POS: Conj|Punct> [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#group EXP@INTERNSHIP: {
   <durch><STEM: Werkstudententätigkeit>
}

#group EXP@INTERNATIONAL: {
   <Auslands\-> (<\,><.+\->)* <POS: Conj|Punct> [TE
COMP_1_1|COMP_1_2|COMP_2_1|COMP_2_2|COMP_3_1|COMP_3_2|COMP_3_3|COMP_4_1|COMP_4_2|COMP_4_3|COMP
_5_1|COMP_5_2|COMP_5_3|COMP_6_1|COMP_6_2|COMP_6_3|COMP_7_1|COMP_7_2|COMP_8_1|COMP_8_2]<>+[/TE]
}

#group EXP@WORK_DESC: {
   ([OD EXP@WORK_DESC_ADJ] <POS: Adj> [/OD] <\,>)* [OD EXP@WORK_DESC_ADJ] <POS: Adj> [/OD] [TE
EXP@WORK] <>+ [/TE]
   |[OD EXP@WORK_DESC_TIME] <> <Jahre|Jahren|jährige>[/OD]<>*[TE EXP@WORK]<>+[/TE]
}

! ########################## TESTING ##########################
! Kenntnisse / Erfahrung in ... -> was ist mit Interesse an/sind interessiert an
#subgroup KNOWLEDGE2: {
[SN]<STEM: sein, POS: V> <STEM: Interesse>[/SN]
}

#subgroup EXP2: {
   %(KNOWLEDGE) (<POS: Prep|Conj>? <POS: Det>?)+ <POS: Adj>?<POS: Nn><POS: Nn|Num|Prep|Punct>*
   (<POS: Punct-Comma><POS: Conj>?<POS: Adj>?<POS: Nn><POS: Nn|Num|Prep|Punct>*)*
   (<POS: Conj|Det>+<POS: Adj>?<POS: Nn><POS: Nn|Num|Prep|Punct>*)?
}

! erweitern um optionale <im Umgang..> oder <im Bereich...>
#subgroup EXP3: {
   %(KNOWLEDGE) (<POS: Prep|Conj>? <POS: Det>?)+ <POS: Adj>? <POS: Nn><POS: Nn|Num|Prep>*
   (<POS: Punct-Comma><POS: Conj>?<POS: Nn>+)*
   (<POS: Conj|Det>+<POS: Nn><POS: Nn|Num|Prep>*)?
}

! <nomen> (...) <conj> : das in der klammer ignorieren?!
```

D.2 SQL Statements (with regards to Hagn (2017))

D.2.1 Find Exact Duplicates

```
SELECT A.ID AS ID1, A.FILENAME AS FILE1, B.ID AS ID2, B.FILENAME AS FILE2
FROM SA AS A, SA AS B
WHERE CAST(A.CONTENT AS BINARY) = CAST(B.CONTENT AS BINARY)
AND A.ID < B.ID
ORDER BY ID1
```

D.2.2 Create a Full Text Index

```
CREATE FULLTEXT INDEX "JOBADV_IDX" ON "SYSTEM"."STELLENANZEIGEN"("CONTENT")
TEXT ANALYSIS ON
TEXT MINING ON
SEARCH ONLY OFF
FAST PREPROCESS OFF
LANGUAGE DETECTION('DE')
CONFIGURATION 'sap.hana.ta.config::EXTRACTION_CORE_EXTENDED'
```

D.2.3 Find Duplicates in Full Text Index

```
SELECT DISTINCT B.ID
FROM STELLENANZEIGEN AS A, STELLENANZEIGEN AS B
WHERE PLAINTEXT(A.CONTENT) LIKE PLAINTEXT(B.CONTENT)
AND A.ID < B.ID
ORDER BY B.ID
```

D.2.4 Flag Duplicates in Full Text Index

```
UPDATE STELLENANZEIGEN SET DUPLICATE = CASE
WHEN ID IN (
SELECT DISTINCT B.ID
FROM STELLENANZEIGEN AS A, STELLENANZEIGEN AS B
WHERE B.ID IN (SELECT DISTINCT ID FROM IDX)
AND PLAINTEXT(A.CONTENT) LIKE PLAINTEXT(B.CONTENT)
AND A.ID < B.ID)
THEN TRUE
ELSE FALSE
END
```

D.2.5 LINGUISTIC Search Provided by SAP HANA

This example illustrates the LINGUISTIC search provided by SAP HANA at the example of the competency “Ability to Work in a TEAM”.

```
SELECT ID, SNIPPETS(CONTENT)
FROM STELLENANZEIGEN
WHERE CONTAINS(CONTENT, 'team*', LINGUISTIC)
ORDER BY ID
```

D.2.6 EXACT Search Provided by SAP HANA

```
SELECT ID, SNIPPETS(CONTENT)
FROM STELLENANZEIGEN
WHERE CONTAINS(CONTENT, '*ability', EXACT)
```

Appendix E: Survey Breakout Sessions

Your feedback matters!

Breakout Session:	The Digital Transformation of Global Bike
Date:	12.09.2017
Hosts:	Ms. Marlene Knigge, Ms. Loina Prifti, Mr. Alexander Löffler UCC Munich, Technical University of Munich

1. What is your general impression of the new curriculum package?

	++	+	o	-	--
Modular structure => Flexibility	θ	θ	θ	θ	θ
Learning Journeys for specific topics	θ	θ	θ	θ	θ
Curriculum presented in web application	θ	θ	θ	θ	θ
Course calculator	θ	θ	θ	θ	θ
Integration of interactive elements (onlineTED)	θ	θ	θ	θ	θ
Integration of links to related SAP UA content	θ	θ	θ	θ	θ
Integration of links to external content (MOOCs)	θ	θ	θ	θ	θ

2. How do you rate the idea of sticking to the GBI-story and keeping the context for this new curriculum?

	++	+	o	-	--
Sticking to GBI-story	θ	θ	θ	θ	θ
New story: GBS as service provider	θ	θ	θ	θ	θ

3. Do you miss topics? If so, which?

....

....

....

Please turn over!

1

Figure 71: Survey "Breakout Sessions" p. 1/2 (screenshot from survey)

4. I like…

....

....

....

....

....

5. I wish…

....

....

....

....

....

Thank you very much for your cooperation and helpful suggestions.

2

Figure 72: Survey "Breakout Sessions" p. 2/2 (screenshot from survey)

Appendix F: Release of First Curriculum Pilot

F.1 Delivery Email for First Curriculum Pilot (June 19th, 2017)

The following email was used to give twenty-nine pilot customers access to the first curriculum pilot on June 19th, 2017:

"Dear Sir or Madam,

in October 2016, we informed you about our work on the new curriculum "The Digital Transformation of Global Bike". This curriculum aims to show the digital transformation [sic!] process of the traditional manufacturing company Global Bike towards a Product-Service-System provider offering Bike Sharing Services for a B2C market. In this curriculum, we cover topics such as Business Models, Industry 4.0, the Internet of Things and Smart Data Analytics, as well as Digital Business Processes using latest SAP solutions, such as SAP S/4HANA. Thereby, we want to address all relevant topics related to the digital transformation [sic!] of businesses.

We are happy to inform you that a first pilot version of this curriculum is now available. Since you expressed your interest in being part of the pilot program, we will provide you with all the necessary information on testing the new curriculum in this email. We are looking forward to your valuable feedback regarding the new curriculum, which will be considered for the final release of the curriculum in September 2017.

Important Information:

You can download all available materials for the pilot program via the following link: https://www.dropbox.com/s/7nwispu8hh0mmqx/Curriculum%20Pilot.zip?dl=0. Please note that we embedded the materials and additional curriculum information into a browser-based HTML application. In order to get access, please download the ZIP archive, unzip it, and open the **index.html** file. It will open in a browser and give you access to all the materials.
For some exercises and case studies, an access to our SAP S/4HANA test system is necessary. If you want to test these exercises and case studies in detail, you can request a trial access from us. You can either use our Service Desk or give us a short answer to this email. If you already requested an S/4HANA trial access beforehand, you will be provided with the access data automatically in a separate email. The Smart Data Analytics exercises and case studies will not be delivered before September with the new HANA release (HANA 2).
During the next weeks, we will contact you and ask for your feedback on the materials. Your feedback is very important for us to revise our materials and finalize them for the official release in September. Therefore, it would be great if you take the time to provide us with your feedback. […]
We are glad to have you in our pilot program and look forward to getting your feedback and ideas. For any questions, do not hesitate to contact us.

Kind regards
SAP UCC Team Munich

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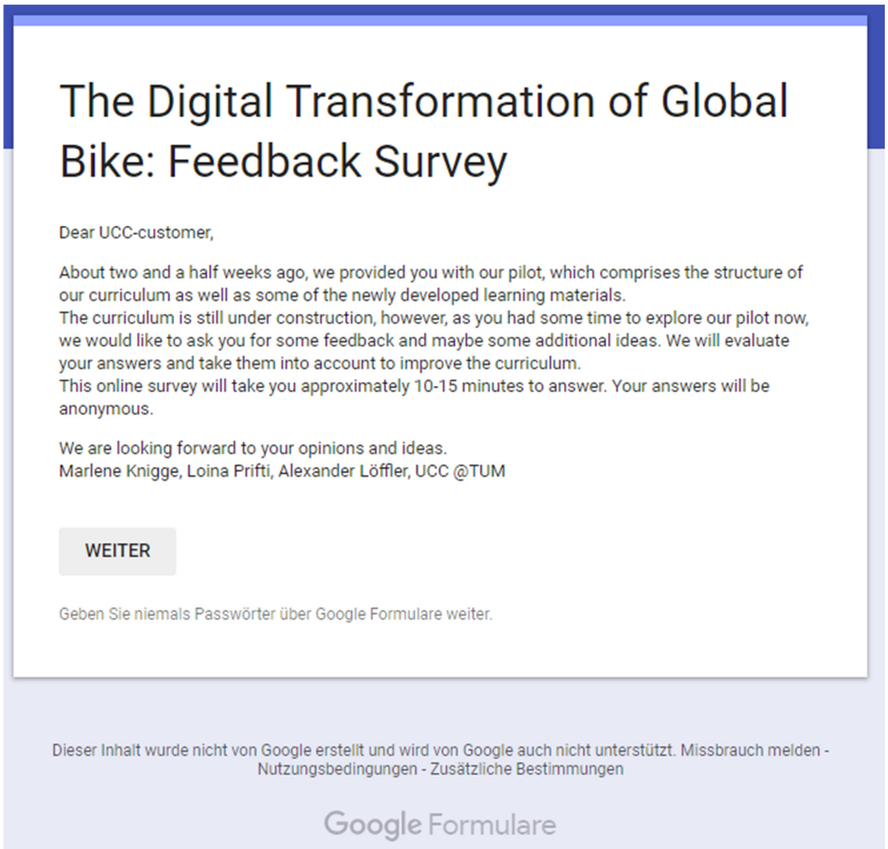
Fax +49 (0) 89 289 18779

E-Mail: uccservice@in.tum.de
Homepage: www.sap-ucc.com/emea

Important Notices:
Please be aware that maintenance of our systems takes place weekly on Thursday between 6 pm and 10 pm. Please do not offer any courses during these maintenance hours.

Please notify your SAP-based lectures each semester to us using following link:
http://portal.hcc.uni-magdeburg.de/irj/portal/course"
(SAP UCC Munich: Project Curriculum Development, 2016 - 2017)

F.2 Evaluation Survey for First Curriculum Pilot (July/August, 2017)



The Digital Transformation of Global Bike: Feedback Survey

Dear UCC-customer,

About two and a half weeks ago, we provided you with our pilot, which comprises the structure of our curriculum as well as some of the newly developed learning materials.
The curriculum is still under construction, however, as you had some time to explore our pilot now, we would like to ask you for some feedback and maybe some additional ideas. We will evaluate your answers and take them into account to improve the curriculum.
This online survey will take you approximately 10-15 minutes to answer. Your answers will be anonymous.

We are looking forward to your opinions and ideas.
Marlene Knigge, Loina Prifti, Alexander Löffler, UCC @TUM

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Figure 73: Evaluation Survey for First Curriculum Pilot: Landing Page (screenshot from online survey)
[76]

[76] As the screenshots were taken from a German machine, some automatically created texts are in German. "Weiter": Next; "Geben Sie niemals Passwörter über Google Formulare weiter": Never provide passwords via Google Forms; "Dieser Inhalt wurde nicht von Google erstellt und wird von Google auch nicht unterstützt. Missbrauch melden – Nutzungsbedingungen – Zusätzliche Bestimmungen": This content was not provided by Google und is not supported by Google. Report abuse – Terms of use – Additional provisions. Translated by the author.

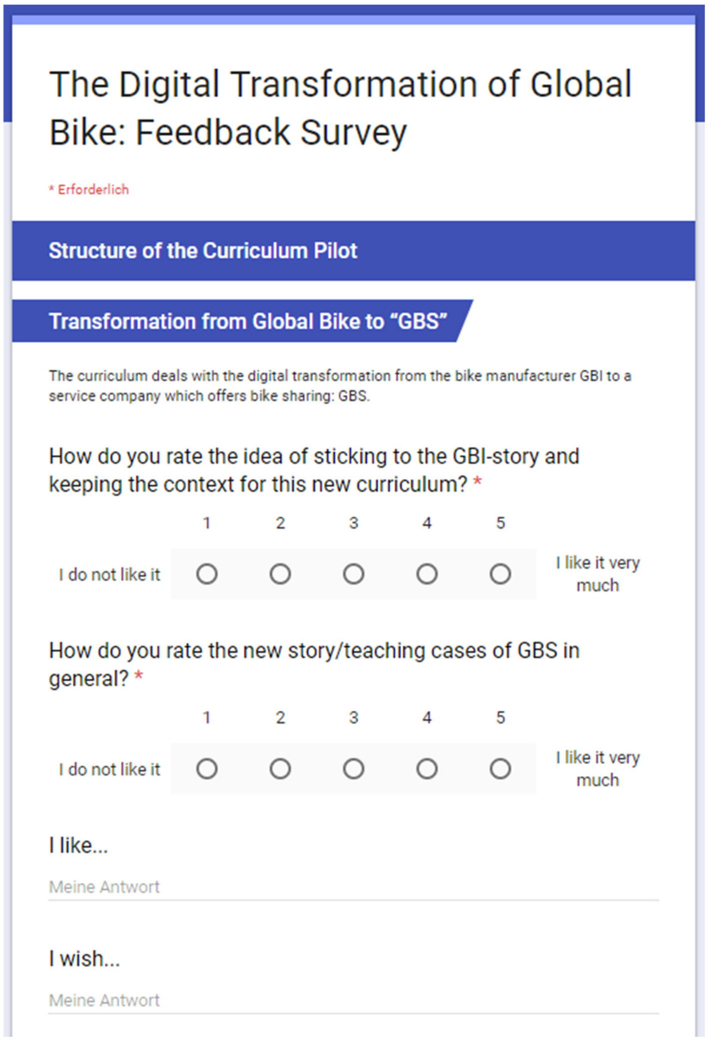
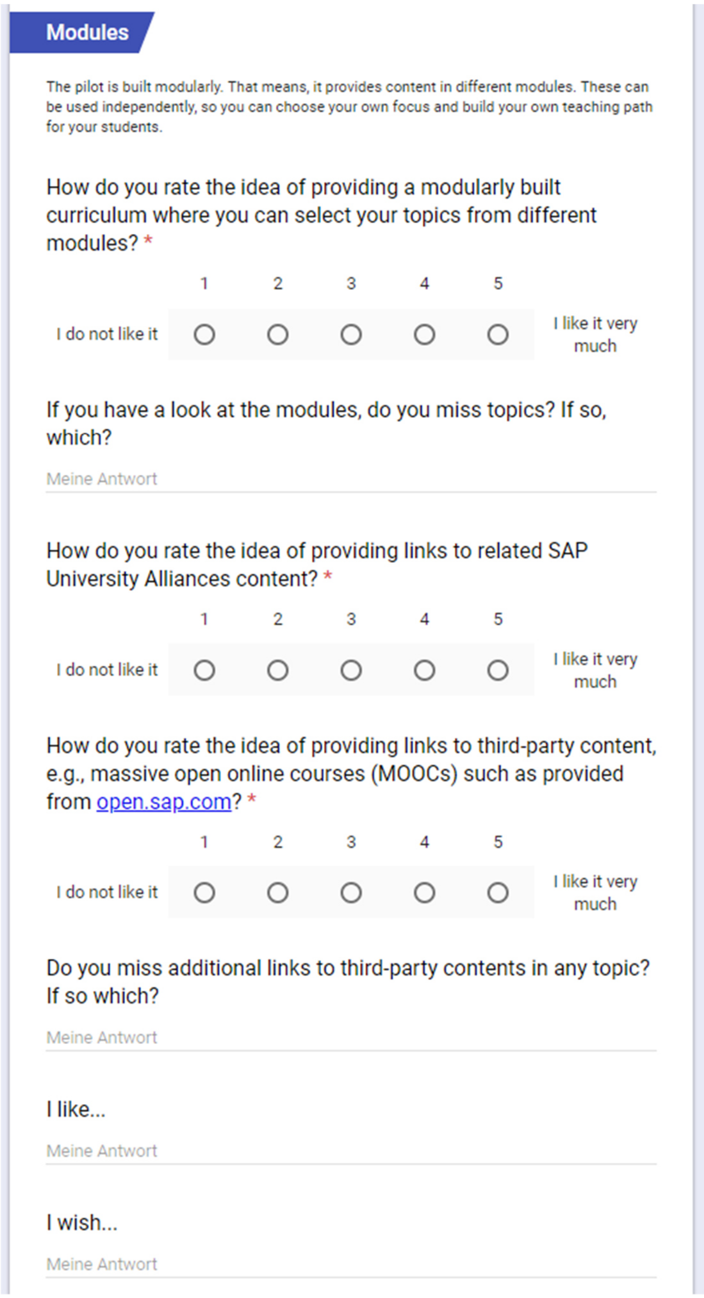


Figure 74: Evaluation Survey for First Curriculum Pilot: Page 1, Part 1 (screenshot from online survey) [77]

[77] As the screenshots were taken from a German machine, some automatically created texts are in German. "Erforderlich": Required; "Meine Antwort": My answer. Translated by the author.



Modules

The pilot is built modularly. That means, it provides content in different modules. These can be used independently, so you can choose your own focus and build your own teaching path for your students.

How do you rate the idea of providing a modularly built curriculum where you can select your topics from different modules? *

	1	2	3	4	5	
I do not like it	○	○	○	○	○	I like it very much

If you have a look at the modules, do you miss topics? If so, which?

Meine Antwort

How do you rate the idea of providing links to related SAP University Alliances content? *

	1	2	3	4	5	
I do not like it	○	○	○	○	○	I like it very much

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? *

	1	2	3	4	5	
I do not like it	○	○	○	○	○	I like it very much

Do you miss additional links to third-party contents in any topic? If so which?

Meine Antwort

I like...

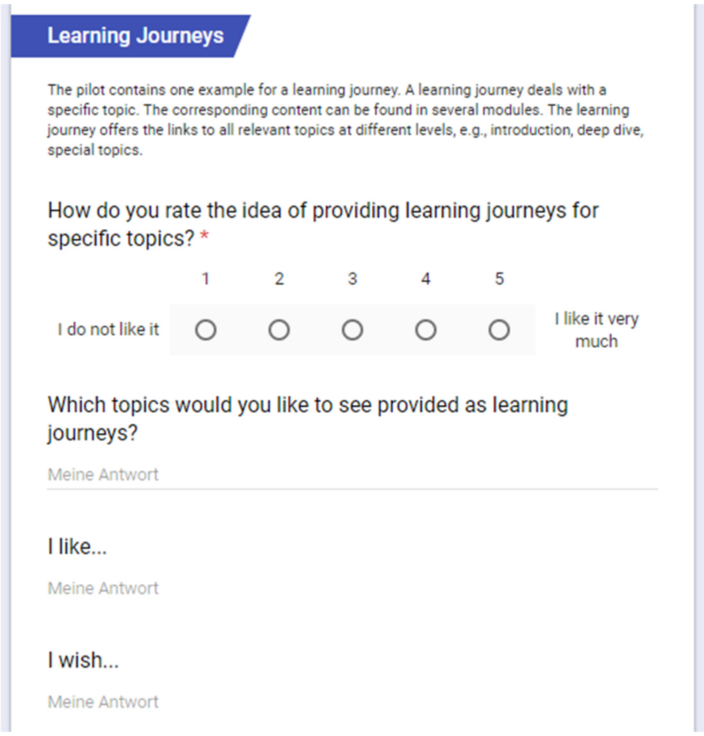
Meine Antwort

I wish...

Meine Antwort

Figure 75: Evaluation Survey for First Curriculum Pilot: Page 1, Part 2 (screenshot from online survey) [78]

[78] As the screenshots were taken from a German machine, some automatically created texts are in German. "Meine Antwort": My answer. Translated by the author.



Learning Journeys

The pilot contains one example for a learning journey. A learning journey deals with a specific topic. The corresponding content can be found in several modules. The learning journey offers the links to all relevant topics at different levels, e.g., introduction, deep dive, special topics.

How do you rate the idea of providing learning journeys for specific topics? *

	1	2	3	4	5	
I do not like it	○	○	○	○	○	I like it very much

Which topics would you like to see provided as learning journeys?

Meine Antwort

I like...

Meine Antwort

I wish...

Meine Antwort

Figure 76: Evaluation Survey for First Curriculum Pilot: Page 1, Part 3 (screenshot from online survey)
[79]

[79] As the screenshots were taken from a German machine, some automatically created texts are in German "Meine Antwort": My answer. Translated by the author.

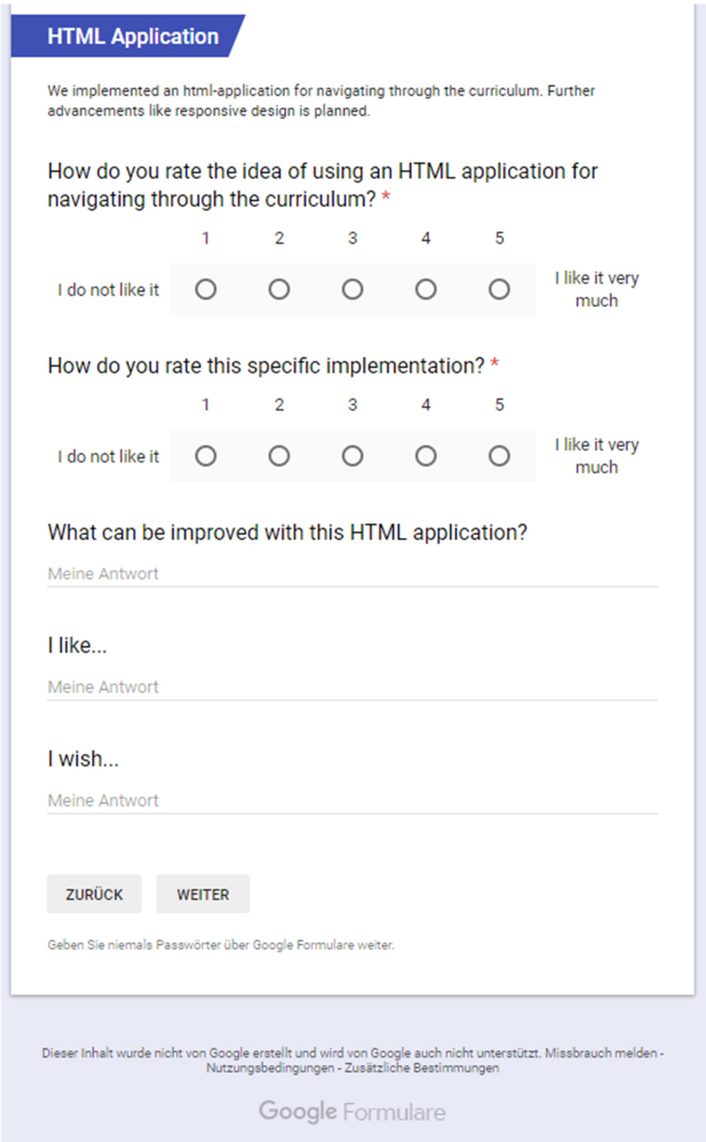


Figure 77: Evaluation Survey for First Curriculum Pilot: Page 1, Part 4 (screenshot from online survey) [80]

[80] As the screenshots were taken from a German machine, some automatically created texts are in German "Meine Antwort": My answer; "Zurück": Back; "Weiter": Next; "Geben Sie niemals Passwörter über Google Formulare weiter": Never provide passwords via Google Forms; "Dieser Inhalt wurde nicht von Google erstellt und wird von Google auch nicht unterstützt. Missbrauch melden – Nutzungsbedingungen – Zusätzliche Bestimmungen": This content was not provided by Google und is not supported by Google. Report abuse – Terms of use – Additional provisions. Translated by the author.

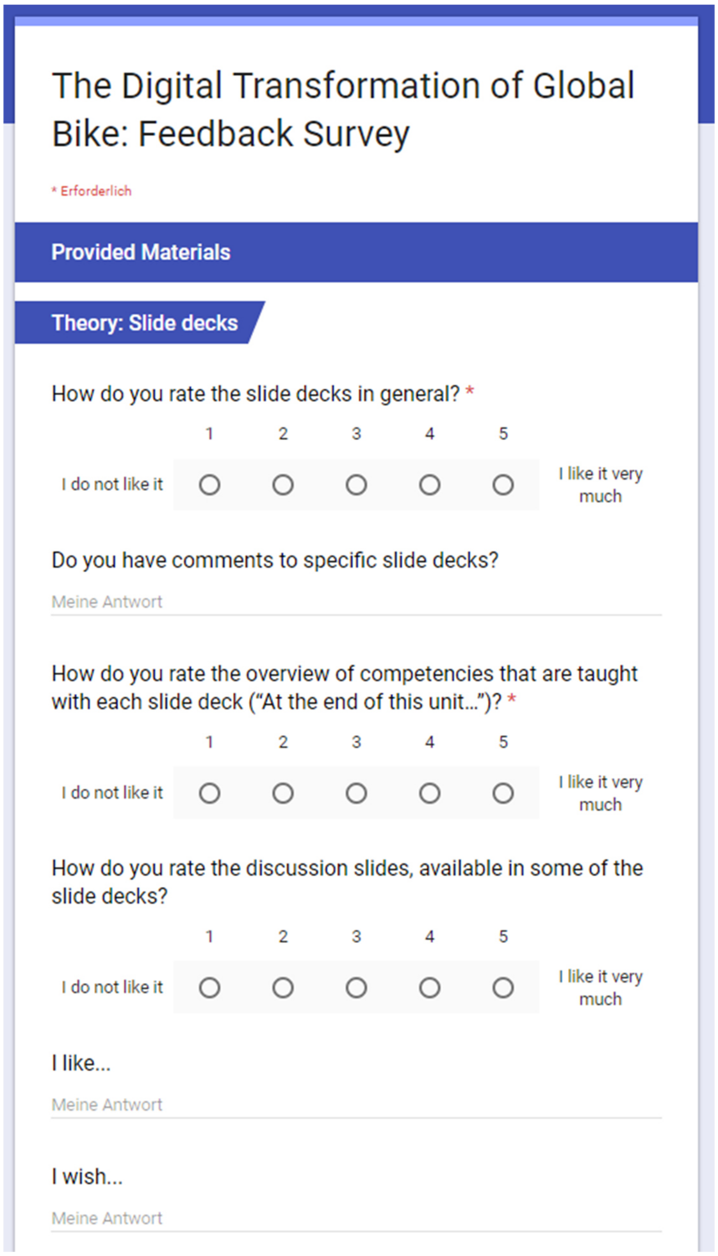
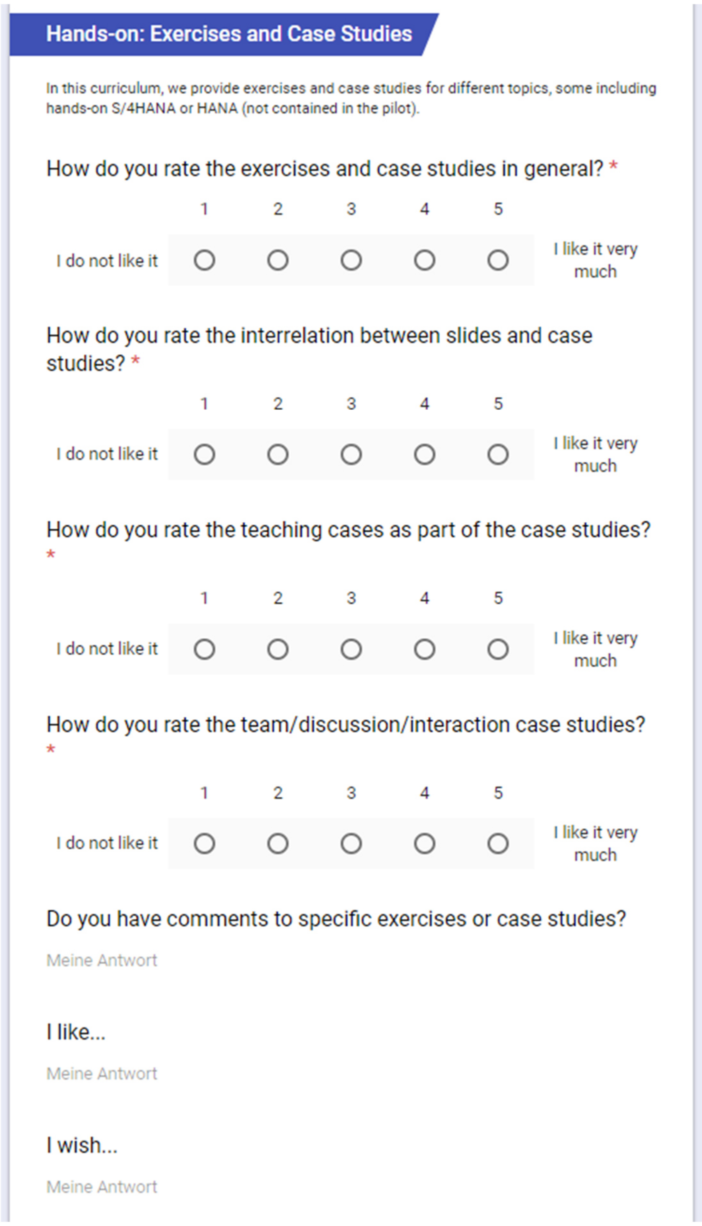


Figure 78: Evaluation Survey for First Curriculum Pilot: Page 2, Part 1 (screenshot from online survey) [81]

[81] As the screenshots were taken from a German machine, some automatically created texts are in German. "Erforderlich": Required"; "Meine Antwort": My answer. Translated by the author.



Hands-on: Exercises and Case Studies

In this curriculum, we provide exercises and case studies for different topics, some including hands-on S/4HANA or HANA (not contained in the pilot).

How do you rate the exercises and case studies in general? *

	1	2	3	4	5	
I do not like it	○	○	○	○	○	I like it very much

How do you rate the interrelation between slides and case studies? *

	1	2	3	4	5	
I do not like it	○	○	○	○	○	I like it very much

How do you rate the teaching cases as part of the case studies? *

	1	2	3	4	5	
I do not like it	○	○	○	○	○	I like it very much

How do you rate the team/discussion/interaction case studies? *

	1	2	3	4	5	
I do not like it	○	○	○	○	○	I like it very much

Do you have comments to specific exercises or case studies?

Meine Antwort

I like...

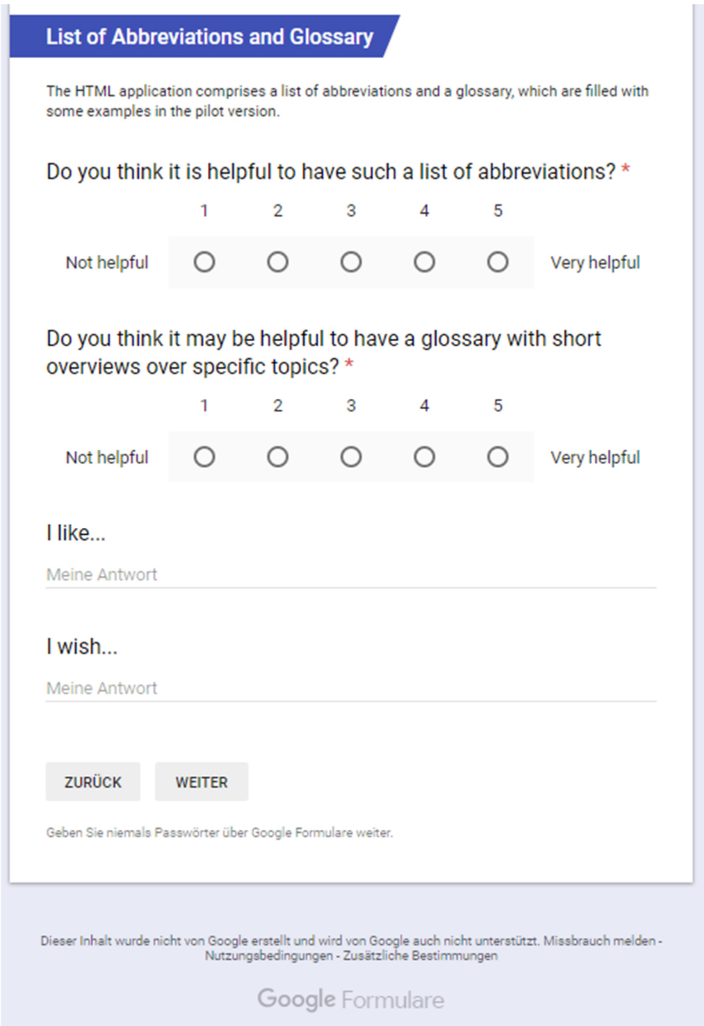
Meine Antwort

I wish...

Meine Antwort

Figure 79: Evaluation Survey for First Curriculum Pilot: Page 2, Part 2 (screenshot from online survey) [82]

[82] As the screenshots were taken from a German machine, some automatically created texts are in German. “Meine Antwort”: My answer. Translated by the author.



List of Abbreviations and Glossary

The HTML application comprises a list of abbreviations and a glossary, which are filled with some examples in the pilot version.

Do you think it is helpful to have such a list of abbreviations? *

	1	2	3	4	5	
Not helpful	○	○	○	○	○	Very helpful

Do you think it may be helpful to have a glossary with short overviews over specific topics? *

	1	2	3	4	5	
Not helpful	○	○	○	○	○	Very helpful

I like...

Meine Antwort

I wish...

Meine Antwort

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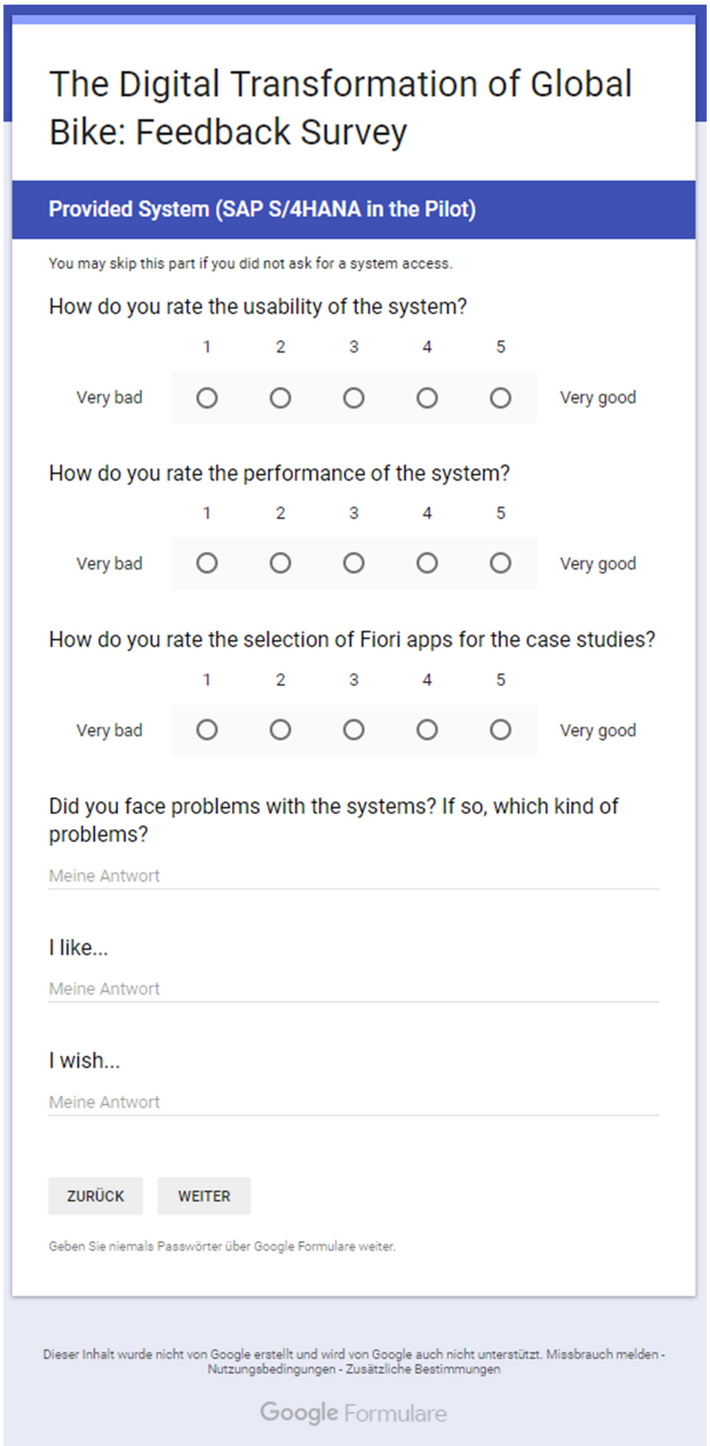
Figure 80: Evaluation Survey for First Curriculum Pilot: Page 2, Part 3 (screenshot from online survey) [83]

[83] As the screenshots were taken from a German machine, some automatically created texts are in German. “Meine Antwort”: My answer; “Zurück”: Back; “Weiter”: Next; “Geben Sie niemals Passwörter über Google Formulare weiter”: Never provide passwords via Google Forms; “Dieser Inhalt wurde nicht von Google erstellt und wird von Google auch nicht unterstützt. Missbrauch melden – Nutzungsbedingungen – Zusätzliche Bestimmungen”: This content was not provided by Google und is not supported by Google. Report abuse – Terms of use – Additional provisions. Translated by the author.



The Digital Transformation of Global Bike: Feedback Survey

Provided System (SAP S/4HANA in the Pilot)

You may skip this part if you did not ask for a system access.

How do you rate the usability of the system?

	1	2	3	4	5	
Very bad	○	○	○	○	○	Very good

How do you rate the performance of the system?

	1	2	3	4	5	
Very bad	○	○	○	○	○	Very good

How do you rate the selection of Fiori apps for the case studies?

	1	2	3	4	5	
Very bad	○	○	○	○	○	Very good

Did you face problems with the systems? If so, which kind of problems?

Meine Antwort

I like...

Meine Antwort

I wish...

Meine Antwort

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Figure 81: Evaluation Survey for First Curriculum Pilot: Page 3 (screenshot from online survey) [84]

[84] As the screenshots were taken from a German machine, some automatically created texts are in German. “Meine Antwort”: My answer; “Zurück”: Back; “Weiter”: Next; “Geben Sie niemals Passwörter über Google Formulare weiter”: Never provide passwords via Google Forms; “Dieser Inhalt wurde nicht von Google erstellt und

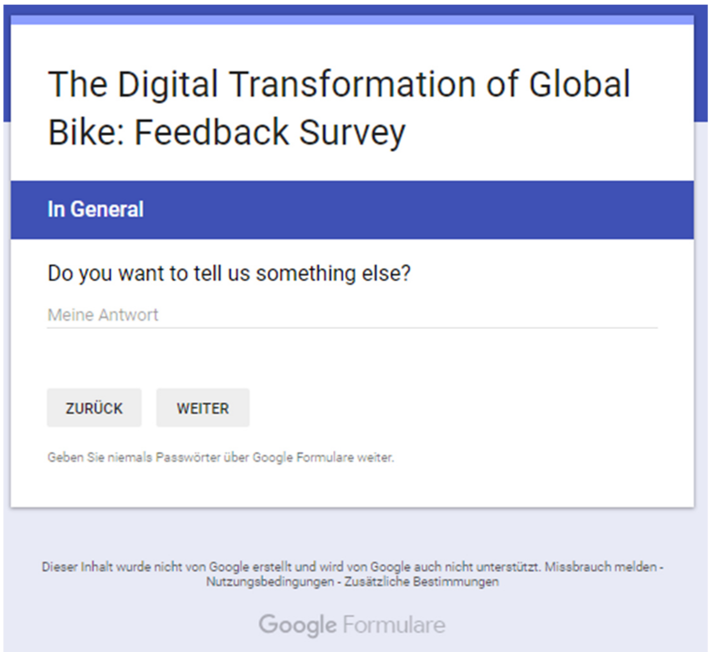

Figure 82: Evaluation Survey for First Curriculum Pilot: Page 4 (screenshot from online survey) [85]

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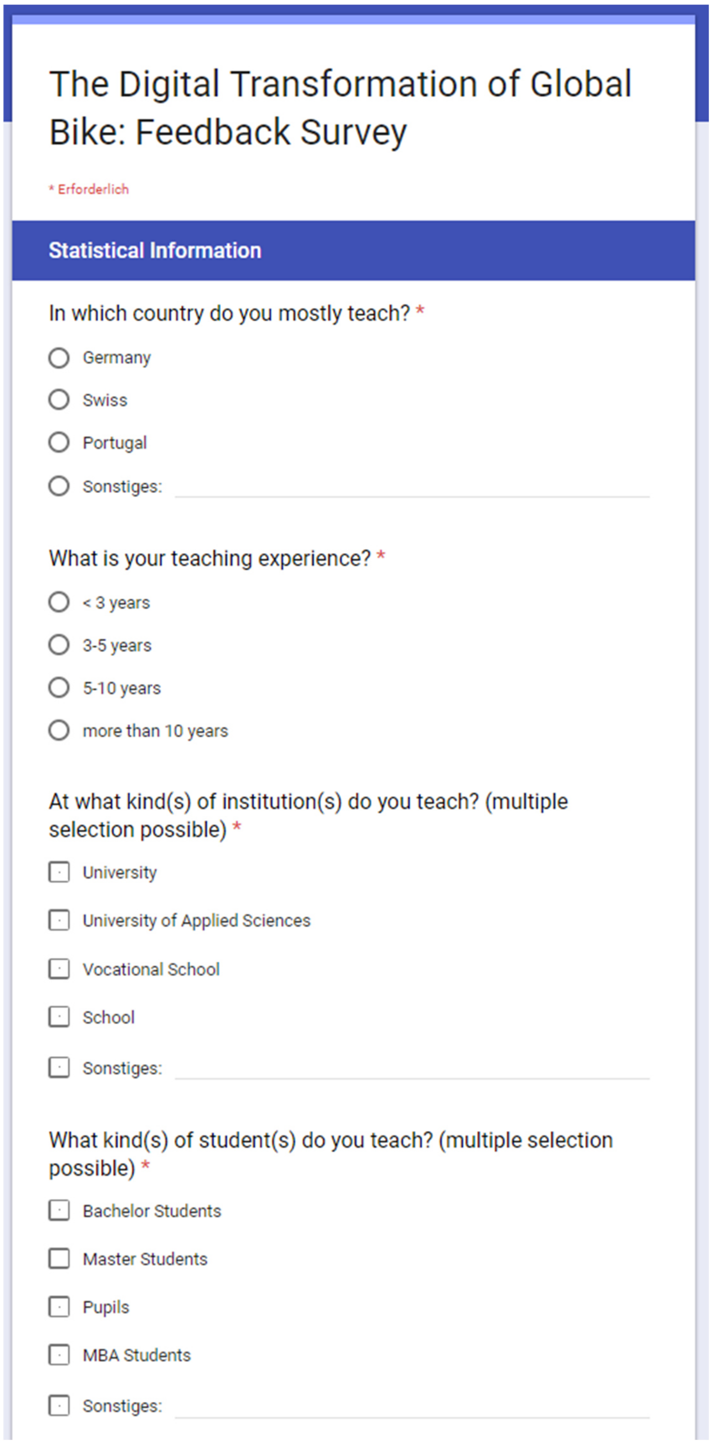
[85] As the screenshots were taken from a German machine, some automatically created texts are in German. “Meine Antwort”: My answer; “Zurück”: Back; “Weiter”: Next; “Geben Sie niemals Passwörter über Google Formulare weiter”: Never provide passwords via Google Forms; “Dieser Inhalt wurde nicht von Google erstellt und wird von Google auch nicht unterstützt. Missbrauch melden – Nutzungsbedingungen – Zusätzliche Bestimmungen”: This content was not provided by Google und is not supported by Google. Report abuse – Terms of use – Additional provisions. Translated by the author.



The Digital Transformation of Global Bike: Feedback Survey

* Erforderlich

Statistical Information

In which country do you mostly teach? *

- Germany
- Swiss
- Portugal
- Sonstiges: ____

What is your teaching experience? *

- < 3 years
- 3-5 years
- 5-10 years
- more than 10 years

At what kind(s) of institution(s) do you teach? (multiple selection possible) *

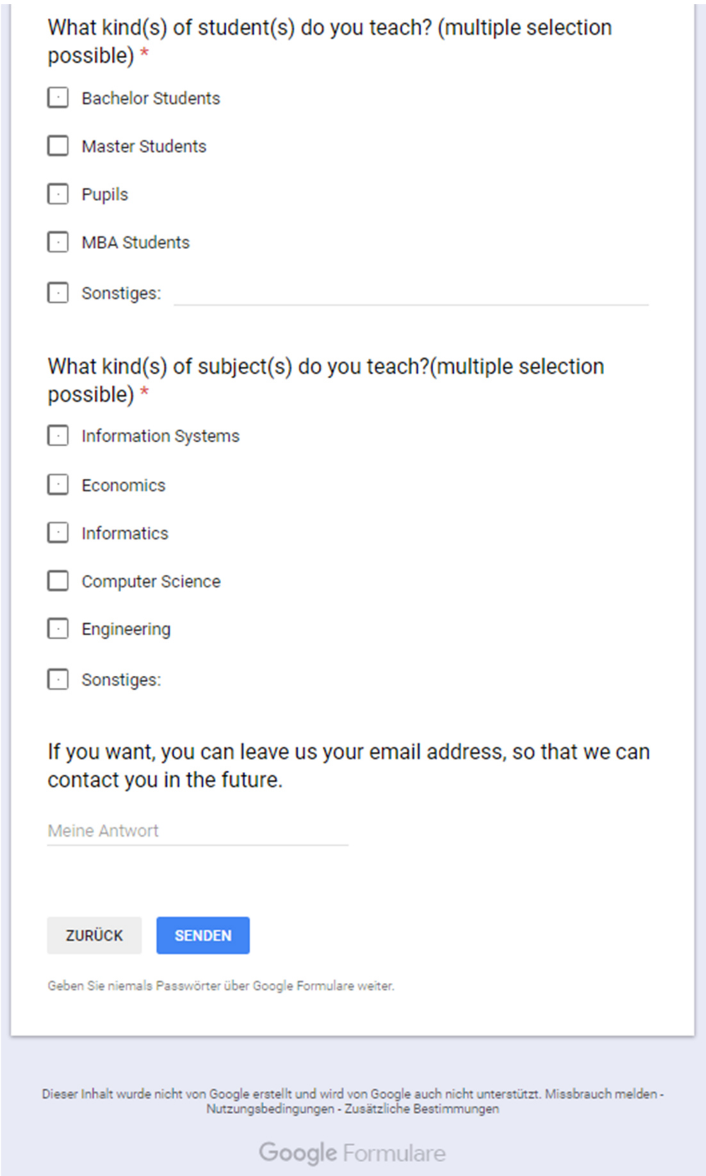
- University
- University of Applied Sciences
- Vocational School
- School
- Sonstiges: ____

What kind(s) of student(s) do you teach? (multiple selection possible) *

- Bachelor Students
- Master Students
- Pupils
- MBA Students
- Sonstiges: ____

Figure 83: Evaluation Survey for First Curriculum Pilot: Page 5 (screenshot from online survey) [86]

[86] As the screenshots were taken from a German machine, some automatically created texts are in German. "Erforderlich": Required. Translated by the author.



What kind(s) of student(s) do you teach? (multiple selection possible) *

- Bachelor Students
- Master Students
- Pupils
- MBA Students
- Sonstiges:

What kind(s) of subject(s) do you teach?(multiple selection possible) *

- Information Systems
- Economics
- Informatics
- Computer Science
- Engineering
- Sonstiges:

If you want, you can leave us your email address, so that we can contact you in the future.

Meine Antwort

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Figure 84: Evaluation Survey for First Curriculum Pilot: Page 6 (screenshot from online survey) [87]

[87] As the screenshots were taken from a German machine, some automatically created texts are in German. "Meine Antwort": My answer; "Zurück": Back; "Senden": Send; "Geben Sie niemals Passwörter über Google Formulare weiter": Never provide passwords via Google Forms; "Dieser Inhalt wurde nicht von Google erstellt und wird von Google auch nicht unterstützt. Missbrauch melden – Nutzungsbedingungen – Zusätzliche Bestimmungen": This content was not provided by Google und is not supported by Google. Report abuse – Terms of use – Additional provisions. Translated by the author.

Appendix G: Flyer for the Curriculum “The Digital Transformation of Global Bike”

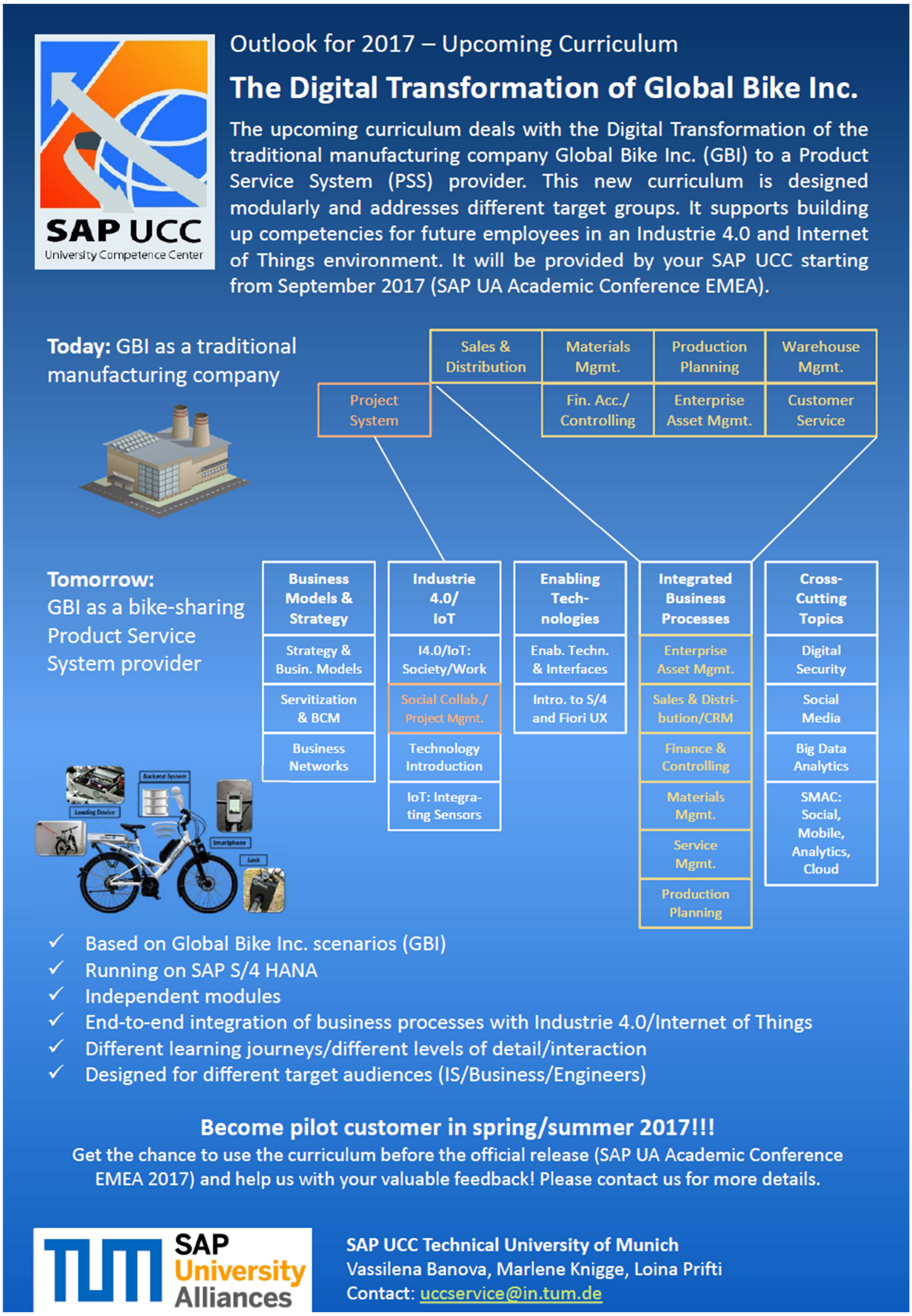

Figure 85: Flyer for the Curriculum “The Digital Transformation of Global Bike” (Knigge, 2016)

Appendix H: Course and Material Evaluation Surveys as Proposed by Keller (2009)

H.1 The Course Interest Survey as Proposed by Keller (2009)

Table 75: Instructions for the CIS (Keller, 2009, p. 279)

Instructions for the CIS as Proposed by Keller (2009, p. 279)
"There are 34 statements in this questionnaire. Please think about each statement in relation to the class you have just taken and indicate how true it is. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear. Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements. Record your responses on the answer sheet that is provided and follow any additional instructions that may be provided in regard to the answer sheet that is being used with this survey. Use the following values to indicate your response to each item. 1 (or A) = Not true 2 (or B) = Slightly true 3 (or C) = Moderately true 4 (or D) = Mostly true 5 (or E) = Very true" (Keller, 2009, p. 279).

Table 76: Questionnaire: CIS (Keller, 2009, p. 279 f.) and Adjustments in the Scope of the Curriculum Project "The Digital Transformation of Global Bike"

No.	Question for the CIS as proposed by (Keller, 2009, p. 279 f.)	Adjusted Question[88]
1	*"The instructor knows how to makes us feel enthusiastic about the subject matter of this course."*[89]	The **lecturer** knows how to make us feel enthusiastic about the **topics** in the course.
2	*"The things I am learning in this course will be useful to me."*	The **theoretical and practical topics** I am learning in this course will be useful to me.
3	*"I feel confident that I will do well in this course."*	I feel confident that I will do well in this course.
4	*"This class has very little in it that captures my attention."*	This class has very little in it that captures my attention.
5	*"The instructor makes the subject matter of this course seem important".*	The instructor makes **the topics** of this course seem important.

[88] Changes are made visible in bold.
[89] All questions quoted in the second column of Table 76 origin in (Keller, 2009, p. 279 f.).

No.	Question for the CIS as proposed by (Keller, 2009, p. 279 f.)	Adjusted Question[88]
6	*“You have to be lucky to get good grades in this course”.*	You have to be lucky to get good grades in this course.
7	*“I have to work too hard to succeed in this course.”*	I have to work too hard to succeed in this course.
8	*“I do NOT see how the content of this course relates to anything I already know.”*	I do NOT see how the content of this course relates to anything I already know.
9	*“Whether or not I succeed in this course is up to me.”*	Whether or not I succeed in this course is up to me.
10	*“The instructor creates suspense when building up to a point.”*	The **lecturer makes the course exciting**.
11	*“The subject matter of this course is just too difficult for me.”*	The **topics** of this course **are** too difficult for me.
12	*“I feel that this course gives me a lot of satisfaction.”*	I feel that this course gives me a lot of satisfaction.
13	*“In this class, I try to set and achieve high standards of excellence.”*	In this class, I try to **[…]** achieve high standards of excellence.
14	*“I feel that the grades or other recognition I receive are fair compared to other students.”*	I feel that the grades or other recognition I receive are fair compared to other students.
15	*“The students in this class seem curious about the subject matter.”*	The students in this class seem curious about the subject matter.
16	*“I enjoy working for this course.”*	I enjoy working for this course.
17	*“It is difficult to predict what grade the instructor will give my assignments.”*	It is difficult to predict what grade the **lecturer** will give **for** my assignments.
18	*“I am pleased with the instructor’s evaluations of my work compared to how well I think I have done.”*	I am pleased with the **lecturer’s** evaluation of my work compared to how well I think I have done.
19	*“I feel satisfied with what I am getting from this course.”*	I feel satisfied with what I am getting from this course.
20	*“The content of this course relates to my expectations and goals.”*	The content of this course relates to my expectations and goals.
21	*“The instructor does unusual or surprising things that are interesting.”*	The **lecturer** does unusual or surprising things that are interesting.
22	*“The students actively participate in this class.”*	The students actively participate in this class.
23	*“To accomplish my goals, it is important that I do well in this course.”*	To accomplish my goals, it is important that I do well in this course.
24	*“The instructor uses an interesting variety of teaching techniques.”*	The **lecturer** uses an interesting variety of teaching techniques.
25	*“I do NOT think I will benefit much from this course.”*	I do NOT think I will benefit much from this course.
26	*“I often daydream while in this class.”*	I often daydream while in this class.

No.	Question for the CIS as proposed by (Keller, 2009, p. 279 f.)	Adjusted Question[88]
27	*“As I am taking this class, I believe that I can succeed if I try hard enough.”*	As I am taking this class, I believe that I can succeed if I try hard enough.
28	*“The personal benefits of this course are clear to me.”*	The personal benefits of this course are clear to me.
29	*“My curiosity is often stimulated by the questions asked or by the problems given on the subject matter in this class.”*	My curiosity is often stimulated by the questions asked or the problems given **[…]** in this class.
30	*“I find the challenge level in this course to be about right: neither too easy not too hard.”*	I find the challenge level in this course to be about right: neither too easy not too hard.
31	*“I feel rather disappointed with this course.”*	I feel rather disappointed with this course.
32	*“I feel that I get enough recognition of my work in this course by means of grades, comments, or other feedback.”*	I feel that I get enough recognition of my work in this course by means of grades, comments, or other feedback.
33	*“The amount of work I have to do is appropriate for this type of course.”*	The amount of work I have to do is appropriate for this type of course.
34	*“I get enough feedback to know how well I am doing.”*	I get enough feedback to know how well I am doing.

H.2 The Instructional Materials Motivation Survey (IMMS) as Proposed by Keller (2009)

Table 77: Instructions for the IMMS (Keller, 2009, p. 283)

Instructions for the IMMS as Proposed by Keller (2009, p. 283)
“There are 36 statements in this questionnaire. Please think about each statement in relation to the instructional materials you have just studied and indicate how true it is. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear. Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements. Record your responses on the answer sheet that is provided and follow any additional instructions that may be provided in regard to the answer sheet that is being used with this survey. Thank you. Use the following values to indicate your response to each item. 1 (or A) = Not true 2 (or B) = Slightly true 3 (or C) = Moderately true 4 (or D) = Mostly true 5 (or E) = Very true” (Keller, 2009, p. 283).

Table 78: Questionnaire: IMMS (Keller, 2009, p. 283 f.) and Adjustments in the Scope of the Curriculum Project "The Digital Transformation of Global Bike"

No.	Question for the IMMS as proposed by (Keller, 2009, p. 283 f.)	Adjusted Question[90]
1	*"When I first looked at this lesson, I had the impression that it would be easy for me."*[91]	When I first looked at this **session**, I had the impression that it would be easy for me.
2	*"There was something interesting at the beginning of this lesson that got my attention."*	There was something interesting at the beginning of this lesson that got my attention.
3	*"This material was more difficult to understand than I would like for it to be."*	This material was more difficult to understand than I would like for it to be.
4	*"After reading the introductory information, I felt confident that I knew what I was supposed to learn from this lesson."*	After reading the introductory information, I felt confident that I knew what I was supposed to learn from this lesson.
5	*"Completing the exercises of this lesson gave me a satisfying feeling of accomplishment."*	Completing the exercises of this lesson gave me a satisfying feeling of accomplishment.
6	*"It is clear to me how the content of this material is related to things I already know."*	It is clear to me how the content of this material is related to things I already know.
7	*"Many of the pages had so much information that it was hard to pick out and remember the important points."*	Many of the **slides** had so much information that it was hard to pick out and remember the important points.
8	*"These materials are eye-catching."*	These materials are eye-catching.
9	*"There were stories, pictures, or examples that showed me how this material could be important to some people."*	There were stories, pictures, or examples that showed me how this material could be important **for the job**.
10	*"Completing this lesson successfully was important to me."*	Completing this lesson successfully was important to me.
11	*"The quality of the writing helped to hold my attention."*	The quality of the writing helped to **keep** my attention.
12	*"This lesson is so abstract that it was hard to keep my attention on it."*	This lesson is so abstract that it was hard to keep my attention on it.
13	*"As I worked on this lesson, I was confident that I could learn the content."*	As I worked on this lesson, I was confident that I could learn the content.
14	*"I enjoyed this lesson so much that I would like to know more about this topic."*	I enjoyed this lesson so much that I would like to know more about this topic.
15	*"The pages of this lesson look dry and unappealing."*	The **slides** of this lesson look dry and unappealing.
16	*"The content of this material is relevant to my interests."*	The content of this material is relevant to my interests.
17	*"The way the information is arranged on the pages helped keep my attention."*	The way the information is arranged **in the slides and exercises** helped keep my attention.

[90] Changes are made visible in bold.
[91] All questions quoted in the second column of Table 76 origin in (Keller, 2009, p. 283 f.).

No.	Question for the IMMS as proposed by (Keller, 2009, p. 283 f.)	Adjusted Question[90]
18	*“There are explanations or examples of how people use the knowledge in this lesson.”*	There are explanations or examples of **how to apply the knowledge in the job.**
19	*“The exercises in this lesson were too difficult.”*	The exercises in this lesson were too difficult.
20	*“This lesson has things that stimulated my curiosity.”*	This lesson has things that stimulated my curiosity.
21	*“I really enjoyed studying this lesson.”*	I really enjoyed studying this lesson.
22	*“The amount of repetition in this lesson caused be to get bored sometimes.”*	The amount of repetition in this lesson caused me to get bored sometimes.
23	*“The content and style of writing in this lesson convey the impression that its content is worth knowing.”*	The content and style of writing in this lesson convey the impression that its content is worth knowing.
24	*“I learned some things that were surprising or unexpected.”*	I learned some things that were surprising or unexpected.
25	*“After working on this lesson for awhile [sic!], I was confident that I would be able to pass a test on it.”*	After working on this lesson for a while, I was confident that I would be able to pass a test on it.
26	*“This lesson was not relevant to my needs because I already knew most of it.”*	This lesson was not relevant to my needs because I already knew most of it.
27	*“The wording of feedback after the exercises, or of other comments in this lesson, helped me feel rewarded for my effort.”*	The wording **[…] in the slides and exercises […] was understandable to me.**
28	*“The variety of reading passages, exercise, illustrations, etc., helped keep my attention on the lesson.”*	The variety of reading passages, exercises, illustrations, etc., helped keep my attention on the lesson.
29	*“The style of writing is boring.”*	The style of writing is boring.
30	*“I could relate the content of this lesson to things I have seen, done, or thought about in my own life.”*	I could relate the content of this lesson to things I have seen, done, or thought about in my own life.
31	*“There are so many words on each page that it is irritating."*	There are so many words on each **slide** that it is irritating.
32	*“It felt good to successfully complete this lesson.”*	It felt good to successfully complete this lesson.
33	*“The content of this lesson will be useful to me.”*	The content of this lesson will be useful to me.
34	*“I could not really understand quite a bit of the material in this lesson.”*	I could not really understand quite a bit of the material in this lesson.
35	*“The good organization of the content helped me be confident that I would learn this material.”*	The good organization of the content helped me **to** be confident that I would learn this material.
36	*“It was a pleasure to work on such a well-designed lesson.”*	It was a pleasure to work on such a well-designed lesson.

H.3 Course and Material Surveys: Background Information Survey

Table 79: Introduction Text to Background Information Survey

Introduction Text: Background Information
Thank you for completing the survey. Now, we have some additional questions to learn more about you.

Table 80: Questionnaire Background Information

No.	Question (possible answers given in each row)
1	In which lecture/practical/training/… did you take part? *Check boxes*
2	Please indicate the name of your study program. *Check boxes, including “Other” (+ text input field), and “No answer”*
3	Please indicate your current study program. *Check boxes: “Bachelor”, “Master”, “No answer”*
4	Please indicate your current semester. *Number input field*
5	Please indicate your gender: *“Female” – “Male” – “No answer”*
6	Please indicate your age: *Number input field*

H.4 Adjusted Instructions for Piloting the Adjusted Course Interest Survey and the Instructional Material Motivation Survey

Table 81: Adjusted Instructions for Piloting the CIS and the IMMS (with regards to Keller (2009))

Adjusted Instructions for Piloting the CIS
Dear students, You have completed one of our SAP practicals (ABAP or Leonardo). We would like to improve the module, and your feedback is important to us. Therefore, we kindly request from you to answer the questionnaire below. 1. There are two pages of statements in this questionnaire. Please think about each statement in relation to the class/instructional materials you have just taken/studied and indicate how true it is. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear. 2. Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements. 1 means disagree, 5 means fully agree. Thank you for participating!!!