eNDUSTRIE 4.0 – A Future-Technologies Qualification Network for Local Businesses

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***Abstract*—The digital transformation and the increasing associated interconnection of devices, which can be referred to as a 4th industrial revolution, will change processes, structures, and technologies in companies. To cope with the fast upcoming developments in the area of Industry 4.0 and to keep up with the capability to develop new innovative products and services, it is necessary for companies to engage a comprehensive and specialized competence deepening. The topics include, but are not limited to: smart manufacturing, energy efficiency, resource conservation life cycle, innovation strategies or security. The goal of the presented future-oriented and tailor-made qualification measure is to increase the research, development and innovation competence in the companies involved as well as the sustainable establishment of innovative knowledge and new cooperations.**

I. Introduction

Digitalization will change processes, structures and technologies in companies, hence, the roles, tasks, and working methods of the employees will change too. The "new" levers for maximizing efficiency and entrepreneurial success are increasingly found in areas, in which different types of cyber-physical systems are massively interconnected and therefore enable new services. New emerging cloud based technologies [1] offer steadily growing features for analysis or operation without the need of high infrastructural investments. With increasing new technologies, novel ways of processing data allow a more targeted control of individual components and promise enormous performance potential, flexibility gains, and energy savings. Throughout the fast development of technology, processes can be controlled better, and energy can be used more efficiently than ever before. Additionally, with Big Data analytics the planning can be more accurate, the batch sizes smaller, and businesses will be able to develop new services and business models from this basis.

However, manufacturing companies will face immense challenges and changes due to this digital transformation. To improve future developments in the field of Industry 4.0, as well as to anticipate and research new, innovative products and services, scientific partners collaborate and commence cooperation with committed companies inside the nationally funded qualification network project called *eNDUSTRIE 4.0* to create a forward-looking and customized qualification measure. These activities concluded into the creation of a 25 day-long interdisciplinary core curriculum, which is presented in this paper. Within the network, the partners identified the strongly demanded needs of the future-oriented topics. Particular emphasis was put on areas in which horizontal permeability of learning outcomes and widely imparting skills are important: digitalization, automation and collaborative robotics, smart manufacturing, resource saving life cycle and cycle management, energy efficiency in production, business models, innovation strategies, and digital design products, or interdisciplinary cross-cutting issues such as safety and security, equal opportunities or rapid prototyping.

This work introduces the planning, the realization and the results of the qualification network measurement and is divided as follows: First, we explore the reasons for innovation in Section II. After that, we explain the methodology in use III, which leads to the preparation of the seminar contents in Section IV. Subsequently we give insight into our compiled knowledge for practical guidance and the lessons learned during the project (section V). Finally, we discuss and conclude our findings on the feedback of the participants and lecturers in chapter VI.

II. Reasons for Innovation

Businesses are currently undergoing a massive process of transformation because of digitalization changing their processes, structures, and technologies imposing immense challenges on them [2]. In particular, in Austria there are up to the present day few to no training offers with this combination and focus on the market. For many companies, often SME but also large enterprises, the subject of digitalization and Industry 4.0 is still primarily "new territory". A study in Germany [3] shows that there are only a few companies that have already built know-how, but that an investment in education [4] - such as the described qualification network - is one of the essential tools for decision-makers [5].

To better anticipate future developments in the area of Industry 4.0 and being able to develop new, innovative products and services, companies need comprehensive and specialized competence training. The existing qualification network can be seen nationally and internationally as a best practice example. Content and didactics are based on the latest international knowledge. The mix of experts, who come from research and development but also from companies, i.e., from practice, represents a unique added value addressing the following areas required for entrepreneurial success. It is important to note that all three topics must go hand in hand to address the challenges successfully:

Technology

The presented qualification network features representatives of leading research institutions and Austrian companies providing technological foundations to the following topics: sensors, automation and robotics, smart manufacturing, data standards and analysis, security, embedded systems, systems on chip, and industrial testing of software on embedded hardware. A unique concept of this qualification network was, that technological topics of interest to participating companies were prioritized and integrated into the curriculum by participating experts of companies, e.g., as excursions, such as: industrial rapid prototyping demonstrations and testing of matearial properties (such as: iron or plaster), hands-on creating distributed industrial control systems according to IEC 61499, or programming industrial and collaborative robots to achieve industrial automation tasks. Particularly noteworthy are the cross-sectional priorities of energy efficiency, energy storage, resource-efficient production and life cycle products to minimize the most significant, multi-dimensional cost factors. With this focus, the project can be differentiated from other offerings that rely purely on process optimization.

Business Model Innovation

In connection with the broad term Industry 4.0, one can often find counterparts that point to hopeful concepts of the 70s, 80s and 90s such as Computer Integrated Manufacturing, Kanban for load-oriented procurement, or early factory of the future ideas, in which some key arguments were not solved, and now these topics are to be resolved with Industry 4.0. The term digitalization describes the already existing and the progressing network connections happening. Every innovation strategy today needs a digital agenda, which includes the development of new business models, in which in best case digitalization creates entirely new possibilities. In computer science, for example, the question of further business models is first formed by software services and made famous by the technology of cloud computing. Understanding the interaction of technologies and business models is the basis for the economic success of Industry 4.0. However, corporate practice shows that due to "silo structures" there are parallel developments slowing down innovation. An important part of the training network is therefore to support companies by innovative strategies in the process of business model innovation. New business models are developed in relation to the technologies mentioned above and the participants are trained in these methods.

People in businesses

Industry 4.0 is the chance for Austria to occupy and retain more than 20 % of its production sector endangered by low-wage production locations. Digitalization is also changing the demands placed on the employees, the understanding of roles and the way work is done and innovated. In a modern, highly-personalized industry that will sustainably shape a digital factory of the future, ideas are needed, which do not replace human labor and disqualify it as vicarious agents of previously programmed operations. Desirably, they perceive, complement and share the role of human beings in the change of dynamics, creativity, and perception of problems. Furthermore, not only will the "things" within the industrial Internet of Things (iIoT) of a factory be interconnected, but also employees in companies will have to work much more across departments in the future. Even customers increasingly participate in innovation processes (open innovation, co-creation). Therefore, the qualification network provides training on often not yet established methods such as Business Design, Design Thinking or Gamestorming. With these techniques, we explore new business models enabled by digitalization, which contributes not only to value creation or firm strategic partnerships between companies but also to higher satisfaction of the people.

III. Methodology

The expectation of the participants in the qualification network project include an increase in the research, development, and innovation skills in the companies involved through participants as know-how carriers, as well as a successful contribution to sustainable establishment of industry-relevant, innovative knowledge and new collaborations. In particular for structural weak regions such as the Austrian Waldviertel close to the Czech Republic, such qualifications are of utmost importance. The qualification measure especially addresses this area in which four manufacturing companies are participating to qualify themselves for this future relevant topic. In this way, structurally weak regions can be improved in terms of know-how, profit, innovation, and networking, which are essential factors to ensure business success. The companies benefit from this initiative through competitive advantage and use of existing synergies.

Therefore, the qualification measure is designed according to a blended learning concept with total efforts per participant capped at 25 days. The share of presence units was deliberately high at 90% to enforce networking and provide a stimulating learning environment without distractions from daily work. The remaining 10% have been shared for home-learning assignments and e-learning tools.

A. Content Definition

The primary objective of the qualification measure is to enable the trainees to profit most from a time-limited but therefore tailor-made and needs-based competence enhancement.

Upfront to the courses for each module, a syllabus, the didactic concept and expected results have been provided by academic and industrial experts to define the scope of the module. Companies at an institutional level have been included to integrate the arising needs of the company employees into the curriculum. Within this step the scientific project team initially drafted a rough outline of competences of the participants.

Nevertheless at the beginning of the project considerable time was used to acquire the know-how of the individual participants and their expectations to adapt the depth of the teaching, content of lectures and learning outcomes to account for the heterogeneous composition of the participants. This process was moderated and guided by teachers and plays essential role of the concept. As result the curriculum quality and accuracy increased by adapting to the changing needs in the companies. Although some teaching material was available in English only, all courses and the e-learning platform have been held in German language, to keep the language barrier as low as possible.

Two things have to be especially noted in the creation of the content of Industry 4.0: First, in order to have the ability to measure the success of the trainees, outcomes for a qualitative target achievement per module have been defined. Regular feedback ensures that the participants can actually implement the information offered in their day-to-day business. Second, we pay attention to a balance between the transfer of knowledge by the scientific partners and the introduction of impulse lectures by the participants themselves to increase learning from established (best) practices and to create a network between the partners.

B. Timeline and schedule

Overall the qualification network is designed for 18 month with a 4 month setup phase, a 12 month execution phase and a 2 month phase out reserved for reporting and review. There have been two major guidelines for the design of the course: 1) training is limited to single day modules to allow easy integration in the workflow inside the company and 2) between the units adequate gaps of several weeks have been introduced primarily to avoid conflicts with daily work but also to allow reflection and consolidation of learnings. In practice each day consists of two different half day units to achieve this goal and offer variaty for better learning. The overall schedule was defined by the scientific project management with the goal of creating a constitutive order of the courses. Technical units have been alternating to business units although business units have been concentrated in the second half of the curriculum to allow companies to use the gained technical know how necessary to develop, e.g. new business models.

C. Didactic Concepts

The didactic methods have been selected according to the contents, coordinated across modules in the preparatory phase and adapted to the qualifications of the participants of the partner companies. The educational working methods we applied for a sustainable communication of the qualification network contents include the following:

- Live demonstrations
- Moderated panel discussions
- Excursions and guided learning
- Experience exchange in free forum discussions
- Specific content for hands-on learning
- Keynote speeches on specialization topics
- Moderated discussions of the participants
- Topic workshops
- Lectures and presentations by experts of the respective disciplines
- Brainstorming and gamestorming activities to use implicit knowledge
- Technological implementation example demonstrations
- Work assignments in small groups to develop individual content items
- Practice application and project related learnings in a hackathon
- Experience reports and exemplary implementation of learned concepts for the expression of innovative ways of thinking through case studies

D. E-Learning Platform

All necessary information and contents are provided on a Moodle e-learning platform, supporting execution of teaching and providing a place for materials of the presentations or additional materials for further deepening or homework assignments. It can be divided into three areas (Fig. 1): On the left hand side a structure of the course contents is presented, which leads the participants to the desired sections of the website. In the middle the course with the module contents is presented. Different types of informations are offered in this section:

1) Slides and materials of the sessions represented with the document icon
2) A questionnaire for a vote on specialized topics on a session represented with the question mark
3) A special agenda designed by cooperation partners, that have hosted the session, symbolized with the blue document icon.

Finally, the right side offers an overview of the upcoming sessions for the participants. In the calendar itself the dates are marked. At the bottom also the next session, which is automatically updated according to the current date, is indicated.

IV. Seminar contents

In the following the different modules and their contents are presented to give an overview about the content but also to describe the rationale on the set focus in the extremely wide area of Industry 4.0.

Kick-off and Introduction

At the beginning a plenary session for all participants has been organized to provide a common overview and to connect all participants. It consists of invited keynote talks to provide industrial experience but also standardization and research

Fig. 1. E-learning platform including calendar, detailed module content and teaching material as well as course materials or questionnaires

trends. We decided to include representatives of three Austrian societies to present their Industry 4.0 relevance. In practical execution of the project these two blocks have been held on two different days.

Collaborative Robotics and Automation

In the first module, participants are given insight in robotic primitives, robot architectures, control paradigms, machine vision and exemplified with intelligent sensor technology for the automatic reduction of power of the robot so that no significant injury risks can occur. In the second module, the participants have the possibility in a one-day hands-on workshop to program the movements of industrial robot arms and to learn the current status of intelligent robotics. Both manual training by *direct positioning* of the gripping tool and trajectory programming are used. Focus is set to experience typical problems, e.g., regarding singularities and estimation of optimized movements. Furthermore, the robot arm is used in a collaborative form. Finally, application and research examples as well as development trends of integration in automation are provided.

Embedded Systems

This module should allow participants to understand the capabilities and limitations of embedded systems. In a theoretic part design paradigms, real-time requirements, microcomputer programming and fault tolerance are taught. In the practical the acquired knowledge can be applied in hands-on exercises. Aside giving this practical experience, a focus is set on testing and automation in modern embedded software development with industrial requirements. Major learning outcome is, that participants know the characteristics of testable architectures and are able to introduce test automation in their projects.

Smart Manufacturing and Industrial Standards

The definition of modern production facilities clarifies the new challenges for automation and control technology. Based on the usual control solutions according to IEC 61131, the missing elements are detected and the IEC 61499 for distributed control systems is checked for problem-solving potential. Essential requirements such as distributable intelligence, aspect-oriented engineering and integration between automation and IT systems are addressed and their impact on efficiency gains in engineering is assessed. Practical exercises with a company automation system solution show how Industry 4.0 automation can look like in this one-day seminar.

Smart Sensors

This one working day session covers the following topics with special regard to smart sensors:

- Industrial communication technology
- Integration with automation
- Communication of sensors
- Diversity of wired and wireless industrial communication systems for different areas of automation
- Creating an understanding of network concepts

Networking and Hackathon event

The full day event was split in two parts. On the one hand every participating company is demonstrating their contributions (products, research, concepts, business models) to make partners aware of the capability already existing inside the project network. On the other hand the hackathon contains a hands-on experience of an IoT Box platform demonstrating the dependencies of the different layers of an IoT system, ranging from sensor data acquisition to data analysis in a database. During the small tutorial, participants learn to measure, store and visualized the gathered data. The goal of the Hackathon is to create an understanding for the necessary (communication and data) relationships through hands-on experience and the design of Industry 4.0 innovations.

Equality and Differences

In this half-day mandatory session, all participants are trained on the subjects of the responsibility for gender affairs regarding equality, plus questions and answers for equal treatment. The group works through examples of how cultural, age, ability, or gender differentiation can be important for product development. Moreover the social impact on skilled workers like possible replacements through auxiliary staff is discussed.

Rapid Prototyping

The one-day excursion teaches and demonstrates 3D printing techniques using different media (iron, plaster, filament) for industrial applications. Furthermore, the testing of industrially usable material properties is discussed, leading to a comprehension for manufactured prototypes and industrial plants.

Security in Sensor Networks

The goal of this module is to raise awareness and to give an introduction to security fundamentals and how they have to be anchored in the company. This module is separated in an informative first one-day block, a homework to make a security analysis for example applications directly from the companies itself and a last unit to deepen the content and discuss the homework. Topics include security mechanisms for cyber-physical systems and security concepts and mechanisms of embedded sensor systems. Guidance on how security can be implemented in resource-limited communication environments in sensor networks is provided, as well as concepts and implementation examples for the connection of embedded and sensor systems are given. In particular there have been information on security analysis of embedded systems.

Decentralized Energy Production and Energy Storage

In a full-day session, the application possibilities and fundamentals of decentralized generation technologies like PV, GIPV and small wind are presented. Basics of electricity

storage and different storing technologies (mechanical, electrical and electrochemical storage) are provided. Various fields of application and strategies and presentation of state of the art, new technologies and developments. Furthermore the session includes the operation of storage systems (network-compatible vs. market-oriented) as well as research activities and showcase of economic and ecological aspects.

Usability

The workshop gives an introduction to usability engineering and user centered design as a holistic development process. During this day the following has been offered: selected methods of user-centered design, return on investment calculations and the measurability of usability, usage context analysis and principles of dialogue design according to ISO 9241, discussion of low-& high-fidelity prototyping, creation of *personas*, usability guidelines and cognitive walkthroughs, and finally the presentation of usability evaluations with test persons via eyetracking to analyze the gaze behavior.

Resource-saving Production - Ecodesign

During a half day workshop, the participants receive the basics of ecodesign, explanations with application examples of current projects and results. Discussion panel and hands-on introduction on an ecodesign software complete this module.

Sustainability

This module is split into three sessions. The first session, *Topic Environment*, presents fundamentals like ecosystem functions or concepts of ecosystem services. The module teaches the basics of life cycle analysis and offers group work assignments on the life cycle of the companies own products or services. A discussion of the relationships between technology and the environment in relation to the own business field with a final presentation of examples of environmental assessments in current research and development projects is held.

Second, the *Topic Society* teaches participants about fundamentals of technology assessment (TA) and socio-economic aspects of the use of technology. In group exercises a TA-creation of a ”sequence matrix” into one selected example are practiced, which is followed by a discussion.

Third, a merging session on the *Topic Sustainability basics* on integrative concepts of sustainable development is carried out, concluding the exercise on the assessment of sustainability using technologies from previous exercises.

Energy Markets 4.0

A brief overview of different power and control energy markets in an half day session is given. Basics of pricing and new requirements caused by the energy transition are demonstrated as well as the preparation and assessment or correction of a simple economic example of pricing and market participation.

Energy Efficiency in Production

A half day session is providing an overview of European legislation and the accompanying national obligations and proposed methods. Taking further insights of energy efficiency into practise, possible measures that should be taken in the companies are discussed as well as the question on the efficiency on the *national energy efficiency law*.

Infrastructure 4.0

This half-day module discusses the role of the city and its infrastructure for Industry 4.0. First definitions of terms and international approaches to a Smart City also being an enabler for Industry 4.0 are given. Trends in individual energy supply are an important topic. Based on the example of Vienna socio-economic approaches to an Infrastructure 4.0 and presentations of demonstration projects are presented.

Business Model Innovation

The theoretical input for development of innovative business model prototypes with Value Proposition Design teaches participants to identify the problems, wishes, and needs of their customers and design innovative products and services. The sessions include learning to use the Business Model Canvas to methodically develop sustainable business models. By analyzing the framework and a market assessment the participants learn to make informed decisions. In a pitch training the participants learn to present their ideas in a convincing way. In accompanying project workshops, participants develop new business models on specific issues and put theory to practice. Further deepening include topics such as Business Model Prototyping, Cover Story Vision, General conditions, SWOT analysis, and market assessment. In assignments the participants develop minimum viable products and a customer development process, design hypotheses and test cases, story-telling, and business models with lean startup methods. This module covers four full days for the participants.

V. Practical Experiences and Lessons Learned

During ongoing seminars, excursions, and sessions several insights were discovered, that will help to develop new courses more effectively.

First, online questionnaires are more likely to be answered when they are hosted on a website without login requirements than in the online course. This is on the hand due to the usability and representation on mobile devices, where most websites offer an adapted view for mobile devices compared to Moodle. On the other hand, the participants gave feedback in one of the sessions, that the ability to answer the questionnaire in “gap times” is increasing the response rate whereas that necessary login to the online platform with sometimes forgotten/non-available passwords was a major reason to postpone the answering, in generally anticipated as a low-priority task.

Second, proper planning is essential, especially for the participating small businesses, changes in dates, time or place need to be announced as early as possible. The companies have to keep up their daily business, produce goods, serve customers requests and many more tasks. Changes in plans or misinformation lead to non-participation of the session.

Third, the handling of information forwarding inside participating institutions could be improved. Some of the companies tend to forward the information about sessions from the executive floor to different employees to train several specialists in certain parts of this educational measurement. It is an organizational challenge, to keep these participants up-to-date without overrunning organizational emails. Upon that, not

all participants were enrolled in the online learning platform at the beginning, primarily due to new personnel assigned to the units during the runtime.

Fourth, although sessions organized at the companies were anticipated very positively they imply high efforts in the required enrollment of participants. Security and access to areas have been of concern. Also trivial things like e-mail clients supported by the companies caused problems. Additionally to the calendar systems described beforehand, appointments are sent out to the official list via Microsoft Outlook. But not all companies use clients that are able to process and send a accept/tentative/decline response for the received appointment and some company policies prevent installation of necessary plug-ins, which would enable this feature.

VI. Discussion and Conclusion

After presenting the lessons learned and the extensive curriculum, the question of benefits for the participants and optimization potentials are to be discussed. To underline the argumentation, we present the final results of the collected feedback. After each session, the participants are asked to provide written feedback for evaluation. With a grading system and a stepwise ranking ranging from "yes", "rather yes", "rather no" to "no", the participants receive the following questions:

- The topic of the session was interesting?
- The time slot for each topic was sufficient?
- Was the speaker professionally qualified and confident?
- Have the contents been conveyed comprehensibly?
- Could you increase your personal skills/competencies?
- Can you use the contents for your professional activity?
- How do you rate the session altogether?

A free-text space on possible improvements or additions on the session concludes the questionnaire.

Across the 23 different module topics, all of the 40 units have been carried out with the following results from the feedback: 95 % of the participants are satisfied or very satisfied with the trainer, while 90 % can use the learned contents for their professional activity, leaving only 10 % of the participants, that could not use certain seminar contents for their work, while this number varied on the topic of the modules. Altogether, the overall rating of the seminars was marked with either good (40 %) or very good (60 %) grades by the participants. The high quality of the seminars led to a high participation rate with an average rate of 10 attending persons per lecture unit, whereas each of the ten participating companies could send, depending on the companies size, from one to two persons per unit. The companies therefore used the possibility to spread the knowledge gathered in the units among different employees, leading to total 42 persons. In only five of the 23 topic modules, one or more companies were completely absent. This was above the expected rate, since the ten lecture-attending companies are located all over Austria.

The praxis-oriented examples are very welcomed by the participants. Some sessions caught particular interest with the wish of further deepening. Two sessions received a critical evaluation (only 80 % satisfaction with trainer, 50 % with content). These two took place within in the early beginning of the module blocks and immediate adaptation of content planning had to take place: More practical orientation, more examples related to fields of participants, less prerequisite knowledge. To avoid such misalignments between expectations of trainers and trainees, for the further module sessions, the trainers have been asked to prepare a brief description of the planned content two weeks prior of the module, which is sent out to participants. From that point on, feedback was throughout positive.

A very positive feedback reported is, that due to the many occasions and opportunities for interchanging ideas and exchanging company or product presentations, new approaches for joint projects have been crafted between some qualification participants during the ongoing course runtime. This strengthens the networking relationships of companies even further and enables them to get access to various competencies, which have been unavailable or not considered before. The overall outcome for companies is received as beneficial and lucrative; however, without the funding scheme of the project *eNDUSTRIE 4.0*, in terms of partial financial compensation for the working time spent in education, for most small and medium sized businesses, it would have been impossible to take part in this qualification network. For some of these small businesses, this has also been the first experience in the cooperation between science and economy, with a positive view on the different mix of the qualification network partners.

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