University-industry Interoperability Framework for Developing the Future Competences of Industry 4.0

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Abstract. The article explores how higher education institutions could engage employers and industry representatives into more systematic collaboration by creating environments for developing future skills of the workforce needed for Industry 4.0. We propose that dynamic work-integrated curriculum has the potential for productive outcomes by allowing learners to quickly contextualize the study content within the functional environment of the workplace, and develop field-specific and self-regulated learning competences through work-integrated learning study process. Research-based design and iterative design cycles were followed to develop the framework and prototyping a supplementing web-service to act as a central layer to facilitate stakeholder cooperation. The results of the study indicated that the implementation of the framework would provide several opportunities for inter-stakeholder cooperation, including accelerating the competency-related feedback loop between the stakeholders, and promoting development of work-integrated learning models to provide possibilities for self-regulated learning and career development.

Keywords: work-integrated curriculum, university-industry partnerships, Industry 4.0, competence development, self-regulated learning.

1 Introduction

Smit et al. [1] predict that Industry 4.0 will bring many changes to the workplace as we know it today, including changes across the content, processes, and environment of employees – e.g. intelligent machines are becoming smarter and affordable, allowing the human workforce to focus on less repetitive and more challenging tasks. Increasing digitization and industrial automation pressure organizations to expand future workforce and integrate more automated, data-led technologies to different work-related practices. Such new technology-driven practices expect the future workforce to employ skills and competences that are not yet known or taught by today's educational institutions. Additionally, organizational structures are changing due to the new operational models, which influence task allocation, coordination, and supervision [2]. While this may increase worker motivation and job satisfaction [3], it will create additional demands to the competency profiles of employees and educational systems that prepare the future workforce [1]. To excel in these novel demanding tasks, the future workforce needs to acquire new competences and deeper expertise to be able to advance their proficiency in future-oriented methods of machinery, technical computing, simulation-based design, etc [4]. Digitization poses transformative changes in production work, and hence pushes industry management and practitioners to constantly re-learn new knowledge, and also knowledge that does not exist yet [5]. With the workplace changes for the employees, employers and educational institutions, the required competences of the workforce are changing increasingly rapidly [6], [7]. Due to this, our society may face a labor force crisis: simultaneous unemployment and skilled workforce shortage, and the collaboration of all stakeholders of employee competencies is crucial to prevent this crisis. A large majority of European Union member states are already reporting recruitment difficulties in skilled labor, with more pronounced shortages in engineering and ICT areas [8]. One of the many causes lies in the considerable difference between what is offered by the educational system and what the labour market actually needs. The current article seeks to contribute into improving the situation by exploring opportunities for enhancing the collaboration between educational institutions and the industry. Representatives of the two fields tend to collaborate on general level, but there is a lack of expertise to develop integrated competency management processes or lifelong learning systems that embody the foundation of technology-intensive economy. Besides partnering to create programs, cooperation is needed to establish new teaching paradigms for developing employees' competences for manufacturing environments or future skills that don't exist yet, as traditional teaching methods only have limited effects [9]. There is a need to improve the quality and relevance of education and making education and training more attractive by strengthening work-based learning in collaboration with industry partners.

In order to achieve this, we propose a framework of university-industry partnerships in Industry 4.0 and prototype a supplementing web-service that provides data-based insight into the competency situation of the labor market to enhance the digital transformation of the stakeholders. The following research questions were formulated:

- What are the current practices and related obstacles in university-industry partnerships and competency development process?
- What are the components of the framework supporting university-industry partnerships and competency management process in Industry 4.0?
- How can the data-informed service support practices in regards to the transformation in university-industry partnerships?

2 Theoretical Background

2.1 Industry 4.0

Industry 4.0 (*Industrie 4.0*) was initially coined by the German government as the term referring to the currently emerging technological changes in manufacturing, and presented officially at the Hannover Fair in 2012 as a future project to be included in Germany's High-Tech Strategy 2020 [10]. The suffix 4.0 indicates that it is the Fourth Industrial Revolution, a continuation to the three previous industrial revolutions. A combination of several technological advancements, Industry 4.0 makes use of information and communication technology, cyber-physical systems, network communications, big data and cloud computing, modelling, virtualization and simulation, and improved tools for human-computer interaction and cooperation [10]. Utilizing these technologies in novel combinations will result in new social paradigms by changing business models and organizational structures, creating new employment forms and even entire professions [1], [11], [12].

However, to achieve the adoption of technological innovation, social innovation must first occur. The latter can only be accomplished with competent workforce: embracing the paradigm of Industry 4.0 in a socially sustainable way requires an enterprise to supplement its technological transformation with workforce training and development programs, to ensure that the labor force is skilled enough to use the novel tools and technologies [13]. Learning processes taking place at the workplace will be supported by intelligent assistance systems that make use of multimodal user interfaces [14]. These Industry 4.0 user interfaces need to be situation-aware, self-reflective, and user-aligned [15]. We argue, that the competency management, education and career guidance systems of Industry 4.0 must follow the same principles.

Most governments in the European Union have prioritized Industry 4.0 and adopted large-scale Industry 4.0 policies to ensure increase in productivity and competitiveness, and advance the technological skills of their labor force [16]. The New Skills Agenda for Europe, one of the initiatives listed in the new European Union industrial policy strategy, sets out a joint skills-related agenda for the union, its member states and stakeholders at all levels [17], [18]. The agenda brings examples of businesses and research institutes cooperation that foster curriculum development, and states that work-based learning is a proven method in developing labor market relevant skills and stresses the importance of business-education partnerships in offering these opportunities to a wider audience [18]. The long-term strategy of the Estonian manufacturing describes that for the development of the required Industry 4.0 competencies it is crucial to establish a very close cooperation between the government, universities, and technology and manufacturing enterprises [19].

2.2 Models of Industry-university Partnerships in Education

Enhancing the partnerships between universities and the industry is therefore a key factor in closing the labor market gap for Industry 4.0. Industry and universities have several interrelated incentives for cooperation and partnership: research support, cooperative research, technology transfer, and knowledge transfer [20]. The current article focuses on partnerships of the latter category: industry's involvement in curriculum development, and cooperative educational programs.

Collaborative Curriculum Development. Strong collaboration between university and industry in creating curricula promotes the successful integration of students and fresh graduates into the labor market [21], and helps develop the employees of industry companies [22]. University-industry collaboration ensures that the curricula developed and delivered by universities is appropriate for training students in state-of-the-art techniques so that the industry is supplied with graduates that meet its immediate and long term needs [20]. However, the accelerating pace of technological, demographic and socio-economic disruption is changing the required skill sets while shortening their shelf-life [12]. The slow feedback between industry and university results in a gap between the existing curricula and the rapidly changing needs of the labor market which can be mitigated by shifting from preparing students for a job to preparing them for a career [23]. The stakeholders, including students, employees, academic organizations, businesses, policy makers, and unions, need to continuously cooperate facilitate these processes [23], [24]. The effectiveness of such cooperation is different among EU countries: in some, these partnerships are already effectively identifying competency needs and adapting their curricula accordingly but in others, such partnerships are not the norm yet [18].

Work-integrated Learning Models. Academic and business organizations need to co-create and implement new formal and non-formal programs, and promote informal learning for the successful implementation of Industry 4.0 [1]. To supplement the academic settings with more practical experience, universities and industries have implemented work-integrated learning models with various integration levels of academic studies and workplace experience [25]. Several projects have developed frameworks for advancing technology-based workplace learning practices. The concept of work-integrated learning and Advanced Process-Oriented Self-Directed Learning Environment (APOSDLE) is an example of strategy using predefined business processes to guide knowledge sharing and collaborative learning at the workplace [26]. Intelligent Learning Extended Organization (IntelLEO) framework was developed for learning and knowledge building through the cooperation of organizations of different backgrounds: business, academic, or other communities, as it includes services for discovering, accessing, managing, and reusing the learning resources of the organizations and harmonizing the needs and objectives of organizations and individuals [27]. For scaling informal learning at the workplace the Learning Layers project was initiated with the aim of supporting workplace learning and gaining integral understanding on the three different informal learning processes: *task performance, reflection and sensemaking*; *help seeking, guidance and support;* and *emergence and maturing of collective knowledge [28].* As the individual-level knowledge that emerges in these learning processes matures, communities may form around this knowledge which can result in conception of new products or adoption of novel standards. These knowledge-maturing processes were investigated thoroughly and systematized into the MATURE social semantic system [29]. All of these projects contribute into the continuous stakeholder cooperation around the practice-based competency development of individuals.

2.3 Competence-based Management

Competence-based management has become central in the effective operation of enterprises due to the need to adapt to increasingly rapid market changes, therefore, competency management systems have become the core human resource tools in organizations [30]. Reviews have been conducted on different competency management systems to gain insight into the various possibilities that these systems offer [30], [31]. The most common use cases for competence management systems include searching for appropriate employees, revealing core competencies, assessing and identifying acquired competencies, identifying competence gap, creating personal development plans, etc [31]. We propose that gathering and aggregating information from such systems of different organizations and applying statistics combined with machine learning approaches on these big data can help accelerate the feedback loop between the stakeholders of labor force competency development. Providing fact-based insight into the labor market competency situation supports universities in proactively updating their courses and curricula, and creates a foundation for inter-stakeholder cooperation around work-integrated learning models. This, however, requires a common vision and strategy from all the stakeholders, and willingness to contribute into advancing towards the common goal – competent labor force.

3 Research Method and Procedure

The study focuses on investigating university-industry partnerships in the context of competency development in the field of Estonian ICT in the emerging requirements of Industry 4.0. In order to address the goal of the study, an interoperability framework and a supporting online tool prototype were developed. The design process followed a research-based design process based on four iterative stages (see Fig. 1): a) contextual inquiry; b) participatory design; c) product design and d) the development of prototype of hypothesis, where the prototype reflects the challenges diagnosed in the previous phases of the research [32].

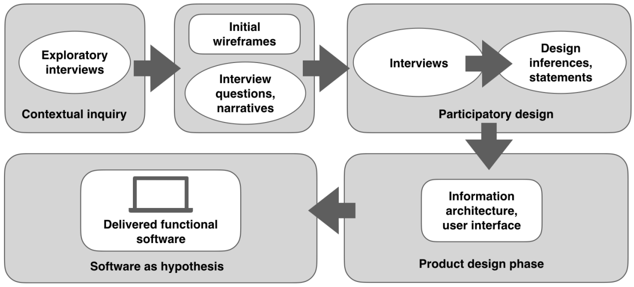

Fig.1. Research design.

The aim of the contextual inquiry phase in the current study was to understand the context, and identify the preliminary design challenges. Participants were asked to describe the challenges around competency management collaboration processes of universities and companies, and name stakeholders of competency development in university-industry partnerships in order to form design groups for the following study phases. Purposive or judgment sampling [33] was used for informant selection to gain expert insight into stakeholder processes. In universities, interviews were carried out with three individuals from ICT curriculum: curriculum coordinator, professor, and student. In business context, interviews were carried out in an ICT business organization that provides services for other industry sectors to help them transition to Industry 4.0. Individuals from five occupations were represented: one human resources and recruitment specialist, two product owners, one key account manager, one product business manager, and two software developers.

Table 1. Data collection participants

Data collection phase	Participants
Contextual inquiry	Curriculum coordinator (1), professor (1), student (1), recruitment specialist (1), product owner (2), key account manager (1), product business manager (1), software developer (2)
Participatory design	Recruitment specialist (2), HR lead (1), engineering excellence specialist (1), university program head (1), lecturer (1), guest lecturer (1)
Product design	Software development engineer (11), business developer (2), recruitment specialist (2), lecturer (2)

In the second phase, participatory design, different stakeholders from the university and industry were brought together to carry out design workshops by commenting on scenarios and contributing to the design concepts. In that phase the scenario-based design method [34] was used to collect user feedback for the initial design ideas. Participants were introduced with several scenarios for students, universities, and industries. Sessions were carried out with four representatives from the ICT sector: two recruitment specialists, one human resources lead, and one engineering excellence specialist. These participants were selected to gain insight into the different competency-related processes across an employee’s career curve. Three university stakeholders were included in the study: a program head, a lecturer, and a guest lecturer. The following is an example of the scenarios.

"Ingrid is the coordinator of the Informatics curriculum in a university. She and the curriculum course lecturers want to make the courses more relevant in the context of the new labor market needs. They use the Pädevusplatvorm to identify the cumulative generic competencies that students should acquire through the curriculum courses based on the occupational qualifications standard 'Software Developer, level 6'. Compliancy visualizations help them identify the competencies that gain an unnecessary amount of focus, and competencies that should be addressed more. The academic staff agree on the changes in courses to align the learning outcomes with the qualifications standard.

Lecturers use the Pädevusplatvorm to gain insight into the statistics of more popular and trending technologies that can be used as practical basis for teaching. For example, Jekaterina decides to rewrite the practical exercises of her Software Development course in Java, instead of C++, as the first is gaining and the latter is decreasing in popularity. As she updates the course materials, she decides to replace the exam of the course with a final group project. She adds 'Java', 'Teamwork' and 'Communication' competencies to the course in Pädevusplatvorm.

Liisi is an informatics student who is looking for an internship position. She uses the Pädevusplatvorm to fill out her profile, including education information and free-form competencies. She has passed several courses and when she marks them in the platform, the system automatically adds several competencies to her profile: the generic competencies derived from the qualifications standard, and the more specific competencies inserted by the lecturers (e.g. Java added by Jekaterina in Software Development course). Liisi additionally maps that she has learned React on her own initiative, adds a self-assessment, and asks for reference from another student – an employed software developer that she has worked on a school project with. She specifies on her profile that motivators for her would be 'friendly team', and 'flexible work time' so that she can continue with other courses in parallel.

Robin, a software developer / PO / QE / recruitment specialist in an ICT company, is looking for an intern or junior for the team. He uses the Pädevusplatvorm to insert the internship position advertisement and conduct a targeted search. He inserts the required competencies 'JavaScript', 'HTML', 'CSS' and 'React', optional competencies 'Java', 'Node.js', and adds some motivators for joining the team: 'flat hierarchy', 'friendly team'. He comes across Liisi's profile in the search results and even though Liisi does not have much experience, she could be a valid candidate based on her competencies and motivation."

Based on the input from participatory design phase, product design phase was conducted where the results from previous phases were translated into information architecture (depicted in Fig. 3) and user interface. The study proposes a unified competency management platform to serve as a central service layer to be used in the competency development related processes of all stakeholders. The platform provides real-time insight into the competency situation of the labor market and enables the stakeholders to carry out data-driven decision-making. To validate design phase results, another set of respondents was included consisting of eleven software development engineers, one business developer, one recruiter, and two lecturers.

The final phase - the software as hypothesis phase - delivered functional software. The results suggest a more holistic platform where different stakeholders collaborate around improving transitions to workplace, and devising new learning methods of various levels of academic-industry integration.

4 Results

4.1 Current Obstacles and Practices in University-industry Partnerships

Different Expectations to Workforce. Study results indicated that even though academic institutions and business organisations share a common interest, competent labor force, there is a rift in industry-university cooperation. Students and new graduates are considered viable candidates for intern or junior positions in ICT organizations, but the stakeholders have different understanding of what is expected from them by the others. In the view of the universities, they should be able to apply their knowledge in practice and contribute at the workplace. However, from industry's point of view, in general they still lack some traits required to perform on the needed level. Due to the changes emerging in the transition to Industry 4.0, there is an increasing need of involving ICT specialists in other industry areas which requires the specialists to be able to adapt to the needs of these areas and apply their knowledge in entirely new contexts. As an example, the participants brought out previous cooperation projects with the electronics and energetic industries: in addition to ICT-related competencies, the specialists had to promptly educate themselves regarding the principles of these other industries to be able to build suitable IT-systems needed by their clients.

Mapping Outcomes and Expected Skills. Participants of the study indicated that it might be not reasonable to try aligning courses or curricula to very specific needs. For example, when it comes to the newest trends in ICT (e.g. technologies emerging with transformation to Industry 4.0), universities have to spend time to create a designated subject, train existing or find new teachers with the required competency, create study materials, and go through the necessary bureaucracy. Even if the aforementioned is done in a short period of time, the technology may still be outdated by the time the students graduate and continue to the labor market. "*We will always teach in the past*," one participant from university stated, "*the first and second year students will emerge to the labor market with a delay*". A similar situation was also noted from business-side: there have been cases where recruitment with a candidate has had to be stopped mid-way because the specific technical skill required for the job was no longer needed. This advocates against trying to include novel, so-called "bleeding-edge" technologies or competencies in courses and curricula, even though they may be prospering at the time. Both university and industry participants reflected that being able to understand the underlying principles is more important than knowing specific technologies. In an ideal, work-integrated learning situation, university would be responsible for teaching these principles while the student chooses the technologies based on the needs of the partnering business organizations. The ability to adapt is becoming essential, especially when the individual works on services provided for other industries. This was pointed out by industry representatives:" Instead *of saying 'I am a Java developer.' or 'We are looking for a front-end developer.' we will have engineers who work on products that they're interested in, regardless of the used technologie*s.". A university representative supplemented that completing a subject does not mean that a student stops practicing. On the contrary – now the student is ready to independently refine the competency as it evolves, improves, expands, and, in case of technical competencies, is eventually replaced with something new.

Collaboration Between University Staff and Industry Representatives. An issue that was noted regarding university courses was that the academic staff's contact with the industry is often limited and, thus, they have a narrow understanding of its processes and production. This results in more theoretical and less practical courses at the university. Yet, according to study participants from both industry and university, it is the more practical experience that contributes most to aligning people with the actual needs of the labor market. Practical experience helps broaden expertise by allowing to experience "real life" and, through this, develop the combination of technical and soft competencies required in the actual workplace. Practical experience would also help academic staff make the necessary connections with the industry's needs and support them in making their courses more modern and relevant.

One possible way to align the university's academic knowledge and industry's practical knowledge is industry internship of the academic staff, which is actually encouraged by the universities. At the same time, the opportunity is often not used due to several issues: replacements of teaching the courses and other academic responsibilities at the university, but also salary issues – should the hosting industry partner pay the salary and based on which salary level? Industry partners also face hesitations: what are suitable projects for academic staff, contracts, non-disclosure agreements, and finding appropriate mentors without inhibiting their contribution and commitment to client projects, to mention a few. It is evident that such process needs in depth vision from the university side and regulations supporting it, but also benefits for the industry partners need to be identified.

In addition to internship of the academic staff at the industry partners, there is a possibility to involve industry representatives to the teaching process as guest lecturers. In this case, some of the aforementioned issues would not play a role, but on the other hand, problems of different nature would arise. Firstly, a practicing specialist, even with high motivation, might not perform on the level of an experienced academic lecturer with excellent pedagogical strategies, due to lack of teaching experience. Secondly, industry people do not have a thorough understanding of university processes, which makes the prospect of teaching intimidating. Study participants mentioned having to provide various documents without any prior knowledge, and described the uncertainties they consequently felt. Third, in universities guest lecturers from industries are welcomed but they are hard to find and it is even harder to persuade them to teach continuously throughout the years, which influences the quality of the curriculum.

Student Internship. In Estonia, organizing professional internship is in general the responsibility of the student which includes finding the suitable organization. While Estonia is known for the high population of ICT organizations, even the larger companies only host a few interns in a year because of different issues: salary aspects, contracts and mentors, but also the expertise level of the students.

One of the worries from the industry partners is that students who are entering internship phase have little to no prior working experience. From industry perspective, these internships are seen as expense of resources: in addition to the mentors' time, the company often has to provide additional resources, e.g. laptops, and services from other departments, e.g. company internal account set-up. On one hand, there is a possibility that the intern compensates these expenses with the contribution she or he makes, and as a result the host organization might have found a suitable candidate for a permanent job. On the other hand, it was described by the industry representatives how interns, or even fresh graduates who enter the labor market, do not have a clear picture of what working in a business organization actually entails: they are not aware of the impact that their actions have on the company, whether it is about keeping promises, abiding to deadlines, or communicating with the client. It was stressed by the participants that for the successful implementation of internships, all stakeholders must be motivated and aware of their own objectives and mission, as well as those of other stakeholders. The sides must agree on the structure, approach and agreements of internships, and be in constant communication. The latter indicates that there is a need for a more systematic and structured cooperation between stakeholders: organized work-integrated curricula which constitute that a great share of learning will occur in a business organization carrying out real work tasks. This approach promotes the development of relevant technical competencies but, more importantly, through active participation in real-life work situations, the students advance in the soft competencies that are difficult to develop in classroom situations: responsibility, ownership, and a general understanding of work life. Industry 4.0 makes use of ICT in different industry areas, therefore the labor force must be equipped with interdisciplinary competencies spanning across multiple industry areas. This brings the issue even further by requiring the students to have practical experience from multiple business organizations of various industrial areas.

From the viewpoint of academia, the scarce amount of potential internship positions is concerning. The latter has led to a situation where, to universities and students, any organization is eligible for hosting internships, because the first and foremost priority is securing a position. Without any filtering, the internship experience may be of questionable nature: the internship programs of organizations are often flawed or nonexistent, and mentors lack the required competencies or attitude. In this scenario, the lesser of the worst outcomes is the waste of the participants' time, but the graver case may result in demotivating them.

All of the study participants unanimously stated that the motivation and attitude of the student, or any individual, are the most important factors in their career paths. In this light, study participants view university students and juniors as highly flexible resource that can grow into various roles based on their own and their employers' needs. Compared to vocational education, which prepares students for specific jobs, university education is designed to provide a wide foundation to encourage multipotentiality and, subsequently, prepare them for entire careers. Such individuals are the perfect employees in the context of Industry 4.0, as their willingness and even inclination to explore new fields allows them to take up new knowledge, technologies, and other competencies on demand as they emerge.

4.2 Framework

Based on literature review and stakeholders' input, a framework was developed to facilitate the university-industry cooperation toward competent labor force for Industry 4.0 (depicted in Fig. 2). The foundation of the proposed framework is the stakeholders' unanimous vision of the cooperation. This constitutes a mutual understanding and agreement on the underlying principles: the common and separate objectives and missions, and responsibilities of the stakeholders. The framework is based on The C^4 Interoperability Framework (C^4IF), an interoperability typology for organizational integration mainly focused but not limited to technology-based integration through Information Systems [35]. In addition to stakeholders (organizations) and their interoperability processes, the new framework incorporates technologies to supplement the processes, and addresses the potential challenges linked to the latter.

Stakeholders. In the context of the current study, there are three stakeholder groups (organizations) to the proposed framework: students and academic staff, awarding bodies and qualifications authority, and employers and employees.

Processes. The framework is designed to facilitate inter-stakeholder processes starting from the selection of curriculum and continuing throughout the entire career of the individual. Based on C4IF the processes fall into four categories: connection, communication, consolidation and collaboration [35].

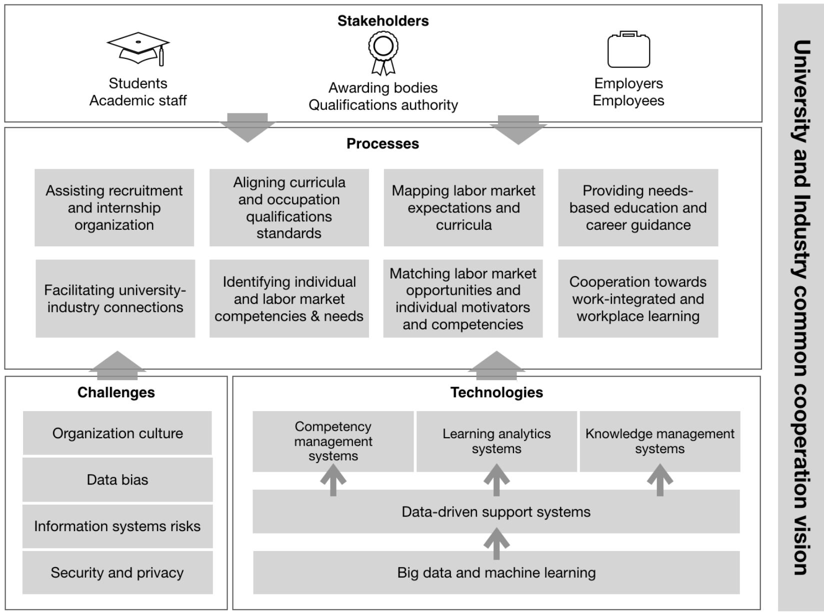

Fig.2. University-industry cooperation framework.

Connection. Connection refers to the ability to exchange signals [35]. In the context of the cooperation framework, connection processes help stakeholders identify each other for further processes. Processes for making connections are related to university-industry connections facilitation, and recruitment and internship assistance.

Communication. Communication is the ability to exchange data, after having agreed on a predefined format or need [35]. Communication processes in the cooperation framework concern the continuous alignment of curricula, occupation qualification standards, individual and labor market competencies and competency needs, and providing access to this information for all stakeholders.

Consolidation. Consolidation focuses on understanding data through interpretation [35]. Consolidation processes in the framework refer to the continuous interpretation of the labor market situation based on data generated during the communication processes to gain a deeper understanding of the gap between labor market expectations and opportunities, curricula, and individual competencies and motivators.

Collaboration. Collaboration, the ability to act together [35], involves cooperative processes undertaken by the stakeholders based on information revealed through consolidation processes: providing needs-based education and career guidance and developing, employing and improving methods of work-integrated and workplace learning.

Technologies. The framework aims to make use of technologies inherent to Industry 4.0, especially big data and cloud computing, simulation, and improved tools for human-computer interaction and cooperation [10]. Data-driven support systems can be developed to foster framework processes. These support systems use big data technologies for data collection and integration, machine learning principles for discovering patterns and providing support for decision making. Data collection and continuous feedback can be automated when using sources such as competency management systems, learning analytics systems, and knowledge management systems.

Challenges. As the framework focuses heavily on Industry 4.0 technologies, the accompanying challenges are also recognized from Industry 4.0 context. The framework processes anticipate collecting and manipulating sensitive data on individual and organizational levels, thus security and privacy challenges arise. Additionally, the framework makes use of information systems which in turn creates the need to mitigate the related risks: confidentiality, availability, and integrity of the corresponding data. Big data and machine learning technologies expand the challenges to include data bias risks: the patterns identified from large amounts of data may prove to be faulty if the underlying data set for model development was biased. Lastly, the refusal to change or adapt organization culture is the major hindering factor when implementing the framework.

4.3 Conceptual Design of the Platform

Automated Data Collection. From HCI perspective, the contribution of the platform is not any novel data entry method, but rather the focus on decreasing manual data entry into several different systems by automatically collecting, unifying and disseminating the information between subsystems. The foremost functionality of the envisioned platform is to serve as a supporting technology for the stakeholder framework and integrate the competency-related information from different sources. This shifts the main focus of HCI considerations from front-end and user interface to back-end services that need to provide persona-oriented contextual data in simple formats. The platform will make use of application programming interfaces (APIs) to become a central data-exchange layer between stakeholder systems such as enterprise competency management systems, university information systems, 3rd party services such as LinkedIn and recruitment portals etc.

Stakeholder Competency Profiles. The main concept of the platform (depicted in Fig. 3) is the competency profile. Each stakeholder has their own model of competency profile and a unified common data model is created based on the occupational qualification standards for data unification. In the context of the study, three extending competency profile models were mapped: individual, university, and enterprise.

Individuals can map their competencies and other relevant information in the format of Curriculum Vitae (CV). CVs consist of general information; experience, such as previous employment, projects, trainings, education and resulting qualifications; technical and soft competencies; and motivational aspects of the individual. For each competency, the individual can add a self-assessment and ask for references from other, more recognized users. In addition to the competencies mapped by the user, the platform also maps the competencies that can be derived from the user's experience. For example, if the user has added her or his university curriculum, the cumulative competencies will be retrieved from the latter. Through individual competency mapping, the platform helps to identify individual competency needs and match individual motivators with labor market opportunities.

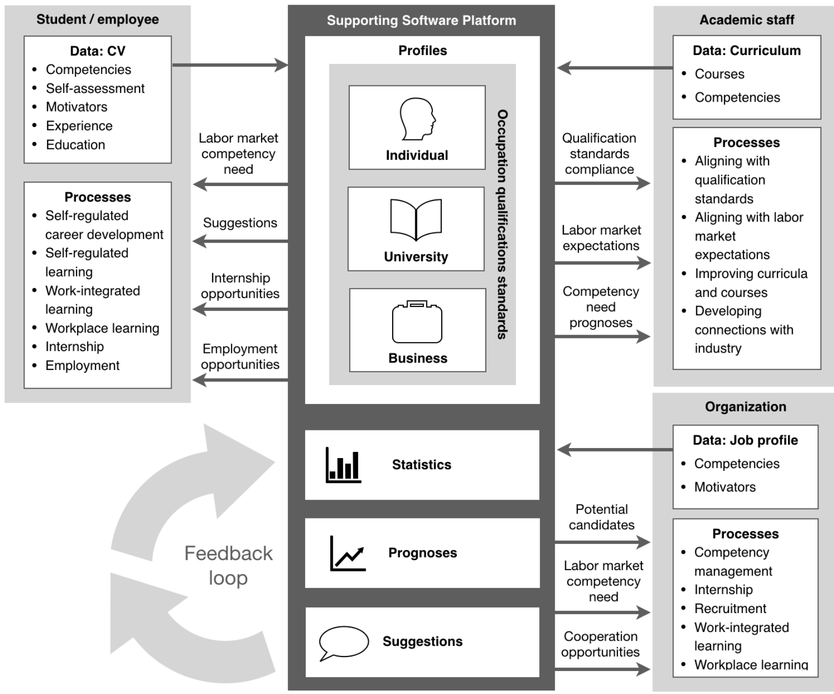

Fig.3. Platform as a larger vision.

Curricula are the competency profile models of universities. A curriculum consists of general information and its courses. Each course in the curriculum develops one to several competencies in the students. In addition to the competencies provided in the occupational qualification standard, universities can attribute additional competencies to courses, e.g. more specific technical or soft skills. When an individual has added a curriculum to their profile, the cumulative competencies are then derived from the qualification standard and summarized in the individual profile. This contributes to the processes of aligning the curriculum with the corresponding occupation qualifications standard and labor market expectations.

Enterprises map their competency profiles in the format of job profiles. Job profiles can additionally be used as basis for targeted search for candidate discovery or job advertisements. Job profiles consist of general information about the job profile or more detailed information about a specific project; required and optional competencies, and the motivational aspects of the job. Enterprise profiles provide recruitment and internship organization assistance, help facilitate university-industry connections, and through these promote work-based learning.

Leveraging Knowledge. Based on the gathered data, the platform provides statistics and visualizations to identify the characteristics of the labor market situation, such as competency gap, trends and prognoses. When comparing the existing competencies in individual profiles with the needed competencies in enterprise job profiles, labor market competency gap is revealed. Based on this information deficit and excessive competencies can be identified. These visualizations help detect the competency connections between different industries to support stakeholders in preparing the labor force for the interdisciplinary nature of work in Industry 4.0. Data from previous periods helps to identify trends taking place in the labor market and predict the more vital competencies of the upcoming periods to make the necessary preparations in time. Based on trends and data from universities, it is possible to forecast which competencies will be released to the labor market in the upcoming periods.

By applying machine learning principles to analyze metadata and identify the inter-relatedness of competencies and the surrounding aspects, it is possible to provide suggestions and recommendations to stakeholders. For example, if a number of enterprise job advertisements includes motivators that are also mapped in the individual's profile, the recommendation module identifies the common needed competencies in these job profiles, and makes a recommendation for the individual to acquire those competencies. This can be supplemented by recommending corresponding courses in a curriculum that the individual is taking, or suggesting a whole curriculum, if the individual is not currently enrolled in any program. Based on the trends, the system can notify the curriculum coordinators or lecturers to inform them when the need for certain competencies is diminishing. This could help the universities to proactively reorganize curricula and courses.

4.4 Stakeholders' perceptions

The participants pointed out several opportunities but also challenges that the suggested framework and application would provide.

Occupation Qualifications Standards. According to both industry and university participants, using occupational qualification standards in their original form as basis for all industry-specific competency models may pose a challenge due to conceptual and technical issues. From the conceptual side, some standards are too vague or outdated. From the technical aspect they do not follow a generic format: platform designs that were made based on ICT qualifications standards were not transferable to other industries. To solve the technical issue, the participants suggested creating a common data model to be used as basis for competency profile models.

Profiles. Study participants from industry endorsed the idea of having a dedicated centralized channel for finding entry-level candidates for junior or intern positions, and made a number of suggestions to ensure the relevance of the software platform. Additionally, they approved the idea of providing potential candidates with information on what is actually needed for the profession they are aiming for. University participants saw the profiles as opportunities to verify the competency structure and relevance of courses and curricula. They suggested that the tool could be used to create course programs and their descriptions, as this is tedious work that each lecturer has to do every year for each of her or his subjects.

Internship Support. Participants stressed the importance of internship as the largest factor in providing students and new candidates with real-life working experience, shaping their mindset, and teaching novel technical competencies. The participants suggested adding functionalities for organizing internships to increase the share of practical education. To successfully advance university-industry cooperation and achieve higher volume internships or practical education programs, it is important to consider the "theoretical" side of such partnerships: finding out the underlying need, objectives and missions of stakeholders, and having a more structured approach to find the most suitable interns. In addition, the agreements between stakeholders must be facilitated. To respond to the needs of organizations undergoing the transformation to Industry 4.0, new internship models spanning across multiple academic and business organizations should be considered.

Manual Data Entry. As a challenge the participants addressed that the platform would not be accepted into general use if using it requires unnecessary additional effort and resources. They noted that the main user effort in the initial design from university-side would revolve around duplicating data: inserting information regarding occupational qualifications standards, and curricula with their subjects. Participants firmly recommended exploring whether these data importation processes could be automated, and warned that otherwise the system would be rejected by end-users. Participants from industry confirmed that organizations with operating internal competency management systems would be interested in integrating their systems via APIs. Additionally, they recommended integrations with 3rd party services such as LinkedIn.

Statistics. The participants noted that the main value of statistics lies in trends visualization. Data from academic and business organizations can be supplemented with 3rd party data e.g. StackOverflow. Forecasts from companies such as Gartner can be used to include novel, fast-spreading technologies that may not otherwise be reflected in the trends and prognoses. This information, in the participants' opinion, is most useful for individuals themselves, and they suggested adding indicators to the statistics section to indicate which competencies are currently booming or trending. Additional value could be created when employing these trends in company branding or long-term recruitment strategies.

Competency, Career and Education Recommendations. Autodidactism is a major factor in shaping an individual's career, according to participants from both industry and university. Being able to learn on one's own initiative is considered one of the outcomes of academic education. The participants were thus enthused by the notion of providing data-driven learning and career recommendations based on the individual's existing competencies, curriculum, and other relevant information. For example, the system could recommend potential competencies, e.g. technical skills with trending popularity among business enterprises, that could be acquired to establish a better position when trying to secure internship or a job. Another example would be to suggest specific trainings, courses or even curricula. This can be supplemented with career recommendations based on the individual's competencies, motivators, etc.

Initiating the Transformation. Organizational changes are required from all stakeholders to enable closer and more broad university-industry partnership. Participants foresee several challenges in establishing this cooperation. From industry side, bureaucracy needs to be agreed on: contracts and non-disclosure agreements with the students and universities, and, if necessary, convey this information to the client organization. Regarding clients, the billing system needs to be more dynamic and contribution based. For example, if the student does not contribute much initially, the client should not be billed for her or his job. Salary levels should be determined and the share of university and business investments have to be negotiated. For example, the business could offer a lower salary for the first course, and increase it incrementally as the student progresses – much like any salary increase. It was pointed out that smaller organizations might not afford losing project money and paying interns so the funding scheme needs to be thought through to include the needs of different organizations. Business participants noted that a mindset shift is required from organizations to view interns and practicing students as investments rather than costly obligations. This includes developing a mentorship system to ensure adequate and enthusiastic mentors. To ensure mentor motivation, a bonus system or other motivators should be introduced. Even more importantly, overworking must be avoided: the business must understand that the mentors' contribution to client projects is lower. Student selection should be done based on mutual interest. As these students are essentially regular junior colleagues, the usual recruitment processes should be followed. The business participants anticipate that the curriculum must be highly dynamic to allow the student to conceptually connect the activities carried out in the enterprise and university. Based on input from business organizations, student evaluation should be organized by the university in a more personal format than filling out Excel forms. It would be better if the mentor, team, and even the organization's client could be interviewed. Business representatives suggested that special interviews be developed together with the curricula that allow to avoid asking the team to give numeric assessments regarding specific skills or knowledge, and focus on the general performance of the student as an employee of the company. Business participants raised questions on who leads the direction of the curricula:"*If only enterprises, then that might not be always the best way of learning innovative and new ways of working and doing things. Enterprises are very practical and look only for today's needs. It should be well-balanced and allow a decent amount of non-commercial/not yet practical studies*". From academia side, the participants suggested that these curricula should be created in cooperation of multiple universities and enterprises. Only then it is realistically possible to provide needs-based education to the students and their enterprises. As a challenge they saw the lack of incentives for industry organizations to enter such partnerships: businesses may not be willing to invest in the cooperation if there is no guarantee that they will eventually profit from it. It was suggested that the government and policy makers should invest into university-industry partnerships. Participants from both stakeholder organizations agreed that to successfully implement the framework and benefit from using the supplementing technologies, critical mass of information and users needs to be achieved.

4.5 Limitations

Due to nonrandom selection of informants in purposive sampling, there may be hidden biases in the study [36] which can be mitigated by complementing the study with quantitative methods.

5 Discussion, Conclusion, Future Work

5.1 Conclusion

The study explored how to broaden the cooperation opportunities of universities and industry organizations to collaboratively shape and develop the future labor force skills needed in Industry 4.0. First, the study mapped the current obstacles in university-industry partnerships and competency development process. The main obstacles discovered were different expectations to workforce in industry and university, insufficient overlap when mapping learning outcomes of university and expected skills in industry, low level of collaboration between university staff and industry representatives, and poorly organized student internships. Secondly, the study sought to map the components of a framework that would support university-industry partnerships and competency management processes in Industry 4.0. A framework with prototypical supporting web-service was developed to help advance university-industry partnerships in the context of future competencies. The framework is designed to help stakeholders connect with each other in the context of Industry 4.0 labor market situation; to aid them in communicating and assimilating information about their situation in order to identify to the gap between what is offered in universities and the actual labor market need; to consolidate stakeholder information to provide continuous insight into the labor market situation through a feedback loop; and to create collaboration opportunities for university-industry to develop work-integrated learning models suitable for the context of Industry 4.0. Lastly, the study explored how data-informed services can support practices in regards to the transformation in university-industry partnerships. The discovered key functionalities of such services were automated data collection, stakeholder competency profiles, statistics and visualization modules, and competency, career and education recommendation systems. Study results reveal that while the representatives of different stakeholders are optimistically minded towards the proposed framework and find value in the supplementing technological concepts, there are many challenges yet to tackle. Changes from all stakeholders will be required achieve the critical mass of users and information for initiating the proposed transformation, including organizational changes, e.g. in bureaucracy and processes, and cultural changes, e.g. changes in expectations toward and communication with other stakeholders.

5.2 Future Work

The current study is exploratory in nature with the cyclical design approach. While the experts who participated in the study sample perceived that the proposed framework and supporting web-service could scaffold the process of developing more systematic university-industry partnerships, the study should be supplemented with several follow-up studies. First, to mitigate the possibility of hidden biases, the study should be complemented with quantitative research. Secondly, the context of additional framework stakeholders could be explored, e.g. by including students, industry employees, and representatives of awarding bodies and qualifications authorities. Third, a practical case study should be carried out based on the previous research that focuses in more detail on the technological aspects and challenges.

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