Proceedings of the 2021 Winter Simulation Conference
S. Kim, B. Feng, K. Smith, S. Masoud, Z. Zheng, C. Szabo and M. Loper, eds.

AN EDUCATIONAL MODEL FOR COMPETENCE DEVELOPMENT WITHIN SIMULATION AND TECHNOLOGIES FOR INDUSTRY 4.0

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ABSTRACT

In the era of industry 4.0 businesses are pursuing applications of technological developments towards increased digitization. This in turn necessitates continuous and increasing demand for competence development of professionals. This paper reports a study of the design of university courses targeted towards professionals and investigate how such an educational incentive can act as a catalyst for application of technologies for industry 4.0, including simulation. Quantitative data is collected from fifteen courses addressing the competence need in manufacturing industry, and the qualitative data includes ten focus groups with course participants from companies. The results highlight that the course design enables knowledge exchange between university and industry and between participants. Moreover the pedagogy of working on real cases can facilitate opportunities for introducing new technologies to management. The study shows that the educational incentive explored can act as a catalyst for application of simulation and technologies within industry 4.0 in manufacturing industry.

1 INTRODUCTION

In the era of Industry 4.0 (I4.0) companies are shaping strategies for applications of new technologies towards increased digitization (Frank et al. 2019; Machado et al. 2019). Among technological drivers for I4.0 are modeling and simulation-based systems (Narula et al. 2020; Eriksson and Hendberg 2020), which can further their relevance through technologies for real-time data collection and analysis to provide information to e.g. manufacturing systems (Frank et al. 2019; Lee et al. 2015). A knowledge area that can contribute as a technological driver for I4.0 is Discrete Event Simulation (DES) (Gasjek et al. 2019). Among other key technologies within I4.0 are i.e. the industrial Internet of Things (IoT), Big Data, Virtual Factory, Autonomous Robots and Cyber Security (Alcácer and Cruz-Machado 2019). While making strategies to increase digitization, from a technical point of view, one of the largest challenges for companies in this transformation is the lack of competence and skills, and consequently the lack of relevant education and training to meet these demands (Teknikföretagen 2016). Hence, there is a continuous and increasing demand for competence development of professionals (Teknikföretagen 2018a; Teknikföretagen 2018b).

The study reported here stems from an initiative of addressing the challenge of meeting industrial competence needs, in Swedish manufacturing industry, in an era of digital transformation. The participating university has a long tradition of close collaboration with industry via research and education, and approaches for co-production have evolved over time (Gustavsson 2018; Hattinger et al. 2014; Hattinger and Eriksson 2020). We apply our understanding of the manufacturing industry’s specific competence needs to develop courses suitable for professionals working full time. The ambition is to meet industry competence needs, where continuous digital transformation and new technologies entail that professionals must develop and thus broaden their knowledge.

The overall aim is to develop a sustainable educational model targeting competence development for professionals. This entails creating a flexible course format on master level to meet knowledge needs in changeable and increasingly digitalized manufacturing. The ambition is to develop a course format that facilitates interest, shows possibilities, and may increase adaption of new technologies among participating companies. We investigate the possibilities and challenges to successfully design such courses. This paper specifically focuses courses within industry 4.0, including simulation. The research question asked is: *How can university courses for professionals be designed to act as catalysts for application of simulation and technologies for industry 4.0 in the manufacturing industry?*

In the following sections related work is reviewed and the research method is described. Thereafter the educational model for competence development is outlined with focus on the design of the courses related to I4.0 including simulation, followed by result, analysis, discussion, and conclusion.

2 RELATED WORK

This section describes initiatives of teaching simulation within university education and highlights related research within the areas of co-production between university and industry through the lens of lifelong learning and competence development.

Several studies have focused on simulation education as part of taught undergraduate programs. For example, Alvarado et al. (2020) reports on a simulation course transitioned from traditional to flipped classroom for Generation Z engineering students. A study of teaching practices through a survey among faculty lecturers and practitioners that teach or have taught simulation in undergraduate courses, highlight the balance between theory and practice, where the teachers consider that simulation projects are valuable to consolidate the learning process (Aurélio de Mesquita et al. 2019). Also Collins et al. (2019) stress the importance of case studies in simulation education to better understand different types of complex problems. This is further emphasized by Martin (2018) stating that real-life simulation cases as part of education provided extensive learning opportunities.

The outlook of universities becoming key actors in regional economic development and knowledge transfer, i.e. the third mission of academia (the other two missions being education and research), is increasingly addressed meaning that expectations of universities are changing (Rubens et al. 2017). University-industry collaboration on education for lifelong learning is one such aspect. Possibilities and challenges for university and industry collaboration as regards research is commonly addressed (e.g. Lyne 2007; Burnside and Witkin 2008; Rybnicek and Königsgruber 2019), though less studied, are the opportunities for collaboration around education for professionals. In today's era of fast technology development it is increasingly important to address the aspects of lifelong learning (Teknikföretagen 2018a; Teknikföretagen 2018b; Kashyap and Agrawal 2019). This entails both finding forms for how university and industry can co-produce education focusing on competence development and how to design education suitable for the industry target group (Hattinger 2018). One example is the enabling of problem-based education in collaboration with manufacturing companies addressed by Andersson et al. (2019), whom stress engagement in co-production activities before, during and after courses. Further, courses needs a suitable balance and pace to make it possible for participants to complete the courses as planned and simultaneously working full time, as dropout rates otherwise may increase (Hattinger and Eriksson 2020). Traditionally university education is not designed with the purpose of targeting industrial course participants (Bruneel et al. 2010). Also Kashyap and Agrawal (2019) address the need and possibility for academia to become a supplier of knowledge to the industry, especially in the era of I4.0. An example with such focus is the study by Chirumalla et al. (2019) reporting a successful initiative of going blended when designing education for industry. Other examples of collaboration around industry competence needs are reported by Gustavsson (2018) and Hattinger and Eriksson (2020).

Several studies highlight the benefits of incorporating real case studies in simulation education for undergraduate students for increased understanding of complex problems and extensive learning. Still, how such case pedagogy can be applied in education for competence development of professionals is less studied. Further, the academic third mission, being the collaboration and sharing of knowledge with surrounding society is becoming increasingly important. Thus, research initiatives that focus on university-industry educational collaboration to specifically support industry competence development have become actualized and significant. At the same time it is vital to realize the growing need for new knowledge in the era of I4.0 within courses such as simulation, virtual factory and IoT. We conclude that the growing competence need in an increasingly digital manufacturing industry caters for research into the design of university education for professionals and benefits from further investigation.

3 RESEARCH METHOD

We followed action research approach including quantitative data collection and a focus group study. The method of action research *"is driven by a desire to bring about change in practice and it strives toward a form of action in order to identify and solve problems"* (Säfsten and Gustavsson 2019). It is a collaboration between researchers and participants from the setting (Bryman 2016), meaning mutual study and the development of solutions to challenges and to uncover opportunities. In our study the researchers are interested in understanding how an educational model with short courses for competence development of professionals can be designed. Professionals taking the courses are participants from manufacturing industry companies and they study in parallel with full time work.

Quantitative and qualitative data was collected over a period of two years, autumn 2018 – autumn 2020. Quantitative data was collected to record course periods, number of courses, number of participants and throughput i.e. percentage of participants completing the courses. To investigate participants views of the courses, data was collected through a focus group study, spanning over two years, autumn 2018 – autumn 2020. The method of focus group was chosen as to aim for an action-oriented and interactive approach where the participants could exchange experiences and reflect on each other's ideas (Säfsten and Gustavsson 2019; Bell et al. 2019). When conducting focus groups, it is important that the interviewer is acting as a moderator capable of taking part in the interaction, but at the same time not be too controlling (Wibeck 2010). In the focus group sessions a semi-structured thematic interview guide was used. Sessions were audio and/or video recorded and transcribed, and additional written notes were taken during the sessions by the interviewer/s. Participants gave their informed consent before taking part. The data from the focus group study was analyzed through qualitative content analysis to interpret text from transcripts and notes, and was categorized into themes of; industry need of course content, incorporation of real cases into the courses, challenges and opportunities of facilitating technological adoption thorough the courses. Further, informal data collection was conducted through participation in meetings with lecturers, course administrators, and information and communications technology (ICT) pedagogues. Workshops with the company network were regularly and biannual conducted and those involved course planning, discussions of course material and content, and giving feedback and exchanging ideas between the course lecturers, project group and company network. Notes were taken and/or recorded as part of the data continuously collected, and integrated in the result and analysis.

To summaries, the overall approach is action research, where we collected both quantitative and qualitative data for the study spanning a period of two years.

4 THE PRODEX EDUCATIONAL MODEL

This section describes the development of an education model with short courses targeting competence development for professionals. Thereafter, the focus is on the courses within I4.0 including simulation.

4.1 The Advancement of an Educational Model for Competence Development

The ProdEx educational model has been developed throughout a longitudinal inter-organizational co-productive project, between university and industry, spanning the years 2013 to 2020. The project was situated at a Production Technology Centre (PTC) affiliated with the university, where research focus on; robotics, automation, simulation, machining, welding, thermal spray and additive manufacturing. The university project group consisted of action researchers, lecturers, ICT pedagogues, coordinators and management. During the project an industry network was built up to include over 50 companies that collaborate with a Swedish University to address manufacturing industry need for competence development. The industry network group consists of CEOs, production managers, HR managers, engineers and production personnel. The university project group and the company network group participate in co-production activities, such as seminars, workshops, meetings and courses to continuously develop new course content and improve the educational model.

The ProdEx education model is designed with short, co-produced, flexible courses of 2.5 European Credits (ECTS) in the field of production technology. The courses are given over five weeks with 4-5 physical or online meetings. The courses are on master level, as this was a requirement from the financier of the initiative, the Swedish Knowledge Foundation (KK-stiftelsen 2021). The courses are given on the formats blended or online. A blended course has a mix of physical and online meetings, whereas the online format means that all interaction takes place on distance. Also the online format means classes, supervision and seminars takes place synchronous i.e. in web meetings. This has shown important to give participants the opportunity to meet lecturers and other participants to encourage co-production and to network (Hattinger and Eriksson 2020). The blended format was the preferred choice until 2020 when the Covid-19 pandemic pushed most courses into the fully online format. However, some courses occasionally require physical labs and testing of simulations in real industrial scale equipment at the PTC laboratory. With permission and precautions taken i.e. limiting to the numbers of people, wearing masks and frequent cleaning, this has still been possible if necessary. Over the first years, the courses where offered on shorter notice in the pace that they were developed. However, the financier required that courses should be advertised as regular university courses, which has been the case since autumn 2018. The courses are free of charge for Swedish citizens and offered through the Swedish national university online admissions service (Antagning.se 2021), where all Swedish university programs and courses are advertised.

When the ProdEx project began in 2013 participating companies suggested courses within engineering, such as machining, computational mechanics and computer aided design. However, as time progressed the courses identified as necessary for competence development moved towards technologies that has advanced in the context of I4.0. The study outlined in this paper focus courses within technologies for I4.0, many of which include different forms of simulation see section 4.2.

4.2 The Courses within Technologies for Industry 4.0 and Simulation Included in the Study

This section outlines content, pedagogy and examination of the nine courses that are given fifteen times over a period of two years, between autumn 2018 – autumn 2020, included in this study. All courses included are 2.5 ECTS on master level. Table 1 summarizes; courses names, format i.e. blended or online and the time period the courses were given.

Table 1: Overview of courses included in the study.

Course name	**Time period *Format***		
Discrete Event Simulation	Autumn 2018 *Online*	Spring 2020 *Online*	
Industry 4.0	Spring 2019 *Blended*	Autumn 2019 *Blended*	Autumn 2020 *Blended*
Cyber Security	Spring 2019 *Blended*		
Internet of Things (IoT)	Spring 2019 *Blended*	Autumn 2019 *Blended*	
Machine Vision	Spring 2019 *Blended*	Autumn 2019 *Blended*	
Industrial Automation	Autumn 2019 *Blended*		
Virtual Factory	Autumn 2019 *Blended*	Autumn 2020 *Online*	
Robotics	Spring 2020 *Online*		
Technology Management	Autumn 2020 *Online*		

The overall pedagogical approach developed through the ProdEx project has been permeated by the concept of co-production between academia and industry. The target group of professionals from industry may mean that the lecturers meet a different group of students, than they are used to, as industry course participants can be unaccustomed to university studies or may not have studied in a long time. Therefor, we have worked to adapt the courses to a pedagogy that can meet this group of working professionals. Rather than emphasizing theory, lecturers have taken advantage of the participants' practical experiences and included real cases, project work and labs, with content often retrieved by the participants from their own companies. It shall be noted that traditional half days written classrooms exams are never used as examination in these courses. Further, the scale of marking is always either pass or fail. Table 2 summaries typical course content and materials, and Table 3 summaries applied examination forms, of which a mix of forms are used in each course. Examination takes place individually or in groups, though the assignments are always individually assessed.

Table 2: Course content and materials.

Lectures	Lectures are synchronously, in the classroom (blended) or through web conferencing (online).
Reading material	Occasionally books are the main reading material, though, courses are short within a specific topic. Hence, commonly booklets prepared by the lecturers are used for content and lab instructions and scientific papers are frequently included. Reading materials is adjusted depending on participants interest or e.g. modeling issues occurring while participants study their cases. Further reading material is included when needed, ensuring flexibility and service, but resulting in higher amount of administration compared to undergraduate courses.
Supervision	Scheduled time for supervision is added between lectures or lab sessions to assist participants on simulation labs, cases etc. Supervision is often online in groups, to give the possibility of discussing common issues. Sessions will be recorded, so that they can be referred to later.
Films	Films are common, either prepared in advanced in recording studios or added throughout the courses, as lecturers will record online sessions and complement with films of specific topics e.g. clarification of a simulation section. This indicates flexibility and service mindedness.

Table 3: Examination forms.

Simulation labs	Computer-based exams, can be performed in classroom, but mostly online.
Physical labs	I.e. robotic, automation, VR/AR. Certain lab exams are difficult to complete online, e.g. experiencing robot movements. Often labs are first simulated, then run in robots in the lab.
Seminars	In seminars participants often present to the class, with following discussion, to facilitate learning and knowledge sharing. Classroom or online, where break out rooms are used.
Quizzes	Rather than long written exams, shorter quizzes are consecutively recurrent (online or classroom).
Projects	Often real cases from participants companies e.g., building a DES model of a production section.
Written reports	Assignments, e.g. essays, lab reports, or PowerPoint presentations, are documented in writing.
Oral presentations	Presentations of project work to the class to learn from each other, e.g. showing DES models of their own operations or studies of technologies within I4.0 applied at participants companies.

5 RESULTS, ANALYSIS AND DISCUSSION

This section outlines results, analysis and discussion of the quantitative data and the focus groups study.

5.1 Results and analysis of the quantitative data

The quantitative data has been collected and calculated for 15 course instances. Table 4 shows the number of registered course participants, the throughput, i.e. percentage of course participants that completed the courses. The last column in Table 4 shows when focus groups took place and how many of the participants that took part, i.e. respondents. The study include 15 courses with a total number of 235 registered participants. Focus group interviews took place at the end of 10 of the 15 courses, with the number of participants in each focus group ranging between 3 and 13, adding up to a total of 72 focus group respondents. There are 5 courses where focus groups were not performed. This, unfortunately was due to lack of resources within the project during those points in time and is marked by a line (-) in Table 4. Yet, the quantitative data for those course instances have been gathered and included.

Table 4: Quantitative data from the 15 courses included in the study.

Course instance	Course name	No. of registered course participants	Course throughput %	Focus groups number / Date / No. of respondents
1	Discrete Event Simulation	7	71 %	**1** 14th of Dec. 2018 / 4
2	Industry 4.0	25	64 %	-
3	Cyber security	16	19 %	-
4	Internet of Things	21	24 %	-
5	Machine Vision	19	47 %	-
6	Industry 4.0	30	77 %	**2** 4th Oct. 2019 / 13
7	Machine Vision	5	80 %	**3** 8th Oct. 2019 / 4
8	Internet of Things	11	82 %	-
9	Industrial Automation	11	82 %	**4** 12th of Dec. 2019 / 9
10	Virtual Factory	18	61 %	**5** 13th of Dec. 2019 / 10
11	Discrete Event Simulation	13	23 %	**6** 3rd of Mar. 2020 / 3
13	Robotics	16	50 %	**7** 17th of Apr. 2020 / 3
12	Industry 4.0	17	82 %	**8** 2nd of Oct. 2020 / 13
14	Virtual Factory	12	60 %	**9** 11th of Dec. 2020 / 8
15	Technology Management	14	50 %	**10** 16th of Dec. 2020 / 5

In Table 1 and Table 4 it can be seen that one course, Industry 4.0, has been given three times and that four of the courses have been given twice, whereas the remaining five courses have been given once in the total time period studied (autumn 2018 – autumn 2020). The average course throughput is 58%, see Table 4, which can be considered moderately high for online and blended courses. However, the result is not systematic, i.e. in the first DES course 71% completed the course, but only 23% the second time. This particular course instance had 13 registered participants, which of whom eight started the course i.e., five did not show up to any activities. Thereafter, another five dropped out early on, some of them reporting that it was due to time limitations and working in parallel. This is not uncommon for individual courses, especially if they are fully online, as courses are advertised through the Swedish national university online admissions service and are free of charge. Entailing it is easy to apply and if admitted easy to register on a course, which in turn means that it is not uncommon to apply to online courses just in case you have the opportunity to take them and then drop out early on e.g., because of lack of time, as there is no penalty for doing so. However, the reasons for such variations give room for further investigation.

5.2 Focus group result and analysis

The focus groups serve both as course evaluation and to gain understanding of how the participants exchange knowledge and bring with them new technologies back into their companies. Most of the focus groups took between 45 – 60 minutes to complete, with the exception of one taking 16 minutes, i.e. course no. 12 in Table 4. In this instance the final seminar on the course ran over planned time and into the time planned for the focus group. Despite being short this focus group is included to give a full picture of the data collection. Most evaluations were performed by one action researcher, but occasionally several researchers took part (authors of this paper, among others). It is important that the lecturers of a course do not take part in the focus groups. This being a strive to anticipate that participants will speak more freely and worry less about raising critical issues without the course lecturers.

In this section we highlight the results of the focus group study concentrating on how the courses can be designed to act as catalysts for application of simulation and technologies for industry 4.0 among participating companies. To analyze this we investigate the participants perceptions of what they have discovered as opportunities for uses in their own companies and what challenges there are to further catalyze the adoption. The data from the focus groups were analyzed across four themes; industry need (Table 5a), incorporating real cases (Table 5b), opportunities of adopting new technologies (Table 5c), and challenges of facilitation of technology adoption through the courses (Table 5c). The citations are indexed e.g. *"F1Ra"*, which refers to Focus group 1 and Respondent a etc. The abbreviation *"I"* refers to Interviewer, sometimes included for clarification as what is referred to.

The discussion held and statements made by the participants as regards industry need of the course content, shown in the excerpts in Table 5a, demonstrate awareness of the necessity of new knowledge and technology. Participants also emphasize the need for advancement to be competitive, and to meet the needs of new potential customers. Further, they realize the risk of not considering new technology e.g., not investing in IT security, as well as stressing the importance of having financial arguments when striving towards implementing new technologies. The aspect of management is raised both as needing convincement for adopting new techniques, but also as management pushing towards smarter production.

Table 5a: Excerpts signifying industry need of the course content.

"Do you want to pursue something based on what you have now applied to the actual examination case? Is there something you feel you can go back into your companies and be listened to?" (I) – Ref. to the course Industry 4.0 *"It's easier to get arguments, i.e. to drive something now because you have better arguments. You could argue why it's a good idea in different way."* (F2Rb) *" For us at (company name) it is more of a requirement from the management to use new technology, it is so that there is more focus on making smarter solutions, we will work in this direction."* (F2Rh) *"If you can just calculate and show it in financial figures, it's quite easy. But, some things become so diffuse that it does not always become easy to calculate, so it becomes an investment that the company has to make, and it can mean taking a chance".* (F2Rh)
"I see one thing that will cost companies a lot and that is IT security. It means that there will be consulting services and that companies will have very high costs. The more you implement data in the cloud and everything has to be connected, the more vulnerability, meaning you will spend more money on buying secure programs and consultants." (F2Rh)
"Everything becomes more automated, security and PLC is important to have with you." (F7Rb)
"We need to be prepared to develop the business, have prior knowledge, have and understanding, my company is neglected and will invest in the future." (F7Rb)
"My purpose to take the course has been to be able to meet requests from (potential) new customers, who have this need. To better understand what my company can offer new customers." (F8Rb) – A participant who owns a consultancy company.
"We learned strategies on how to think about technology. How to think about implementing new technology." (F10Ra)
"More (people) at a higher level (at the company) should take the course." (F10Rb) *"I have brought with me tools and strategies that can be used at management level."* (F10Ra)

The excerpts in Table 5b highlight that the course participants appreciate when they can connect the course content to their own company's operations, apply solutions in their organizations, and get the opportunity to work on examples of real cases. The aspect of introducing new technologies to management may be facilitated by working on real cases as there can be a greater opportunity for the participants to present their course work to managers and get their attention if they have worked on real cases.

Table 5b: Excerpts signifying the aspect of incorporating real cases into the courses.

"Yes it was fun to look at your own problems like that. The downside is that you had to put extremely much effort into gathering data, so it was not so focused on simulation. But it was more like a real problem, so in that way it is very useful and it is easier to be able to connect it to your own reality as well." (F1Rd) – Ref. to a case where participants build DES models of their own operations as part of the examination.
"The last task was it useful? Because this task was connected to what you do in your own operations." (I) *"Yes I think it is very important that it is connected, that all such examples are cases from reality."* (F1Ra)
"Can you give examples of activities and methods for disseminating knowledge in your company during and after the training?" (I) *"Through improvement work, implement it and see solutions in a different way so everyone gets involved."* (F5Ra) *"Presentation to the management team."* (F5Rb)

The excerpts in Table 5c focus on the opportunities of technological adoption through the courses and address the examples where participants highlight that they build simulation models of real business cases.

Table 5c: Excerpts signifying opportunities of facilitating technological adoption through the courses.

"Will you be able to use this project (the DES project case) now back into the company?" (I) *"I think we all (referring to the other course participants) will be able to do that, but I will probably not use this as much as my colleague here, who will use this tool very much in the future. But, for me it was important to understand what you can use it for and so on."* (F1Rd)
"I work with process development at work normally as well, but I have never had a tool like this, even though I dreamed of it." (F1Ra) – Ref. to the DES software
"Have the content of the course met expectations?" (I) *"Beyond expectation. Reached the goal with a bang."* (F3Ra) *"We understand more areas of use, as during discussions the course became broader than what actually specified from the beginning."* (F3Rb)
"The course was necessary for me to be able to use the appliance to be purchased (at the respondents company)." (F3Rc)
" I feel strengthened in opening my own business when I have seen what the technology can add and I know how to use a robot, and got a good understanding of production in general. I have also gained knowledge that allows me to imagine working in industry with robot and robot vision." (F3Ra)
"For my part it (the industrial automation course) was good in my work role. I have a fairly new role, so I now understand what it's about and what the concepts mean. It was great for me." (F4Rc) "It sounds like you are actually taking it with you in real work life right away?" (I) *"Yes, I do."* (F4Rc)
"How can you use what you learned in the course in relation to your work?" (I) *"The tool (DES) if set as should will give clear indications where the problem lies, get clarity, see major changes, and indications towards different outcomes. The examination of mirroring reality went well despite the time pressure. I was left hungry to complete it to be able to do the simulation completely correctly."* (F6Ra) *" I will continue on my project, helping others to get better. This is just the beginning of getting tasks. I see that it (DES) can live on."* (F6Ra)
"The first step was to learn more. The next step is to try to implement as much as possible. Those who participate from (company name) can now sit down and think about how we will proceed to take the next step forward within the company." (F8Re)
"This (the participation in the course) has led to a lot of discussions at work. Now I can use the knowledge and keep up with the conversations. I cannot only use the buzzwords in the subject, but have gained more in-depth and actual knowledge." (F9Rf)
"We (company) have previously wanted to apply the subject in the workplace, but did not understand the meaning of it. Now we have a grasp of the subject and will start implementing it when we have the knowledge." (F9Ra)
"I am an production technician and work with improvement projects. I have gained good insight into various techniques and tools." (F10Rc)

The real business cases and scenarios are simulated as part of the course and the participants emphasis that they intend to continue to use and extend those models. There are examples showing a comprehension of the benefits of DES as a tool for process development. The participants realization of the possibilities with simulation and their ambition to continue and extend the use of simulation highlights that there are possibilities through course participation of increasing the adoption of simulation in their work and at the work places. Another example of immediate adoption of new knowledge is one where the company is investing in new equipment, and where the participant explain that the content taught in the course has been vital to learn this new technology. There are further examples where participants stress that the new knowledge is necessary for them as individuals at work, and also for their companies to step forward into new technologies. Moreover, it seems that the new knowledge facilitate discussions in the work place on how to continue to apply and move further with the technology use.

The excerpts in Table 5d indicate that adoption of the new technologies, e.g. discrete event simulation is seen as interesting to apply further in their companies. However, there are challenges regarding greater application, a major one being time limitation. The courses are short and it is known that e.g., simulation is challenging to learn and especially data collection is time consuming (Robinson 2014). It may therefor be difficult to reach full implementation of new technologies within the scope of one 2.5 ECTS course. Also the aspect of being able to bring your new knowledge and ideas to management is mentioned.

Table 5d: Excerpts signifying challenges of facilitating technological adoption thorough the courses.

"You really lack a good tool where you can show how the process works and what weaknesses you have and what strengths you have and what should we invest in to get rid of the weaknesses. What we have today is experience through the daily follow-ups and there are some Excel sheets you can make, but this (the DES SW) creates a completely different dimension to this. But you have to understand this (DES SW and method) because otherwise it takes too long." (F1Ra)
"I will use this (DES model) in the example I showed today and then I know I have at least three more places where we could use it. It's just a matter of having time." (F1Ra)
"What happens now is that when I do a simulation, I have to present it and it ends up with the technology department and the management team. From there, they make a decision, should we do something or should we just state that this is how it is for us and that is how it must be. But that's the way I can use the tool and spread how we use it. … And it's like, it's going to be evidence. This increases the pressure on the information." (F1Ra)
" I have worked and not understood and then taken the course and now understand a little more. It is good as an overview course (for I4.0) and then go deeper." (F8Ra)

5.3 Summary of Result and Discussion

We have studied how university education for professionals can be designed to facilitate increased applications of simulation and technologies for I4.0 in the manufacturing industry. The result from ten focus groups, provide a rich view of how participants perceive how the new knowledge from the courses can be applied in their work and contribute to the digital advancement of their businesses.

The responses from the professionals taking the competence development courses show that they grasp the importance of keeping up with technological change as a competitive business advantages and exemplifies how through the new technologies they can develop their business e.g. offer more to customers and attract new customers. Further, they foresee the need for change because of technological development, and realize that this may for the company mean taking chances that will cost, but may be more costly if not addressed e.g. need for increased IT security. Most participants are engineers working closely with production, thus they do not hold management positions. Though, interestingly they highlight that the courses have given them confidence and arguments to raise new ideas to management. Ideas for technological change which can facilitate that the companies move forward with digitalization initiatives. Several participants point out how they, after the course, specifically will assist in spreading the new knowledge at their companies, and they discuss that management also needs more knowledge of the opportunities with of I4.0, including simulation.

Further the data demonstrates possibilities of knowledge exchange between academia and industry and between the course participants. The courses mixes participants from different manufacturing companies, mainly from the south west of Sweden. Though as the concept is spread participants have joined from companies all around Sweden. Depending on the total number of course participants on a course, the mix of companies normally vary between three to eight. Occasionally there are also regular master students that take the courses on top of their regular studies. The course participants appreciate partaking and listening to each other's presentations of the examination tasks, i.e., real cases and simulation models from different companies. This gives them perspectives and can further their knowledge within their own company. Even course participants who come from the same company, but first meet in a course, benefit from interaction and exchange. This indicates that within companies knowledge on technological advancement can exists in some areas, but has not reach all colleagues. This means that the course instances can facilitate that participants learn from colleagues within the company, as well as from participants from other companies, and they find synergies and like-minded people they otherwise would not have encountered.

The course format of the educational model described was blended from the start (in 2014) and from 2018 some courses were offered fully online. This meant that in the spring of 2020 when the first wave of the Covid-19 pandemic hit, lecturers that had worked with this course concept were better prepared and could adjust faster and more easily into full distance mode of teaching. An advantage with the online mode is that it has increased the opportunities for companies, based at longer distance from the university, to participate in courses, meaning reaching industry further afield. Also, the online mode has forced lecturers to develop new solutions and forms to visualize and conduct simulation labs online.

It has been exemplified that the educational model and course format can address and facilitate the adoption of simulation and technologies within I4.0. Thus, supporting companies development towards increased digitalization. We also highlight the knowledge exchange enabled through the course format as seemingly appreciated and valued by course participants.

6 CONCLUSION

The research presented in this paper focuses the impact of an educational model with courses targeted at professional competence development, and question how this educational incentive can act as a catalyst for application of simulation and technologies for industry 4.0 in the manufacturing industry. The results show that participants realize the need for new knowledge as individuals, as well as for the development of their companies. The study highlights how the course participants intend to continue to extend the use of the simulation models they build in the courses and how they anticipate adoption, into the workplace, of new technologies learned. There seems to be an embracement of the possibilities with simulation and other I4.0 technologies and a wish to spread the potential. Enabled by the courses the participants have found the vocabulary to explain new technologies and they have sharpened their arguments concerning the importance of digitalization and necessary change when approaching management. The aspects of reaching the interests from management as regards new technologies and knowledge is recurring throughout the data collected. This indicates the importance of management support and occasionally the lack of understanding from management as regards the significance of digitalization. The participants exemplify how working on real cases, such as building simulation models of their own production, gives an immediate use of new tools learnt. However, courses are short and participants voice that they have got a general knowledge of the course content. Thus it is a beginning of moving forward with simulation and other I4.0 initiatives, but not to the extent of being fully implemented. If aiming towards a higher degree of implementation, catalyzed by courses, the educational model needs further development. When designing new courses the project group and company network representatives have worked jointly. However, the aspects of difficulty in reaching management noted by the course participants demonstrate that further development of the courses needs added and adjusted involvement from management. The educational model, where participants and lecturers co-produce content through pedagogical forms such as projects, cases and presentations, facilitates knowledge exchange between academia and industry and in between the course participants. This form of sharing knowledge raises understanding of possibilities of the technologies for increased digital transformation of their businesses. In addition, there are examples of how working on real cases can act as facilitator of new technologies to management. We stress that the third mission of academia, collaboration and sharing of knowledge with surrounding society, is increasingly important. This entails mutual exchange of practical and theoretical knowledge between university and industry, and among industry participants. To summarize, co-production between university and industry is essential for successful educational design aiming to meet competence need and technological challenges faced by businesses today and in the future. The results highlight that the educational model, with its short courses for professionals, can facilitate digital transformation and act as a catalyst for greater application of simulation and technologies within I4.0 in manufacturing industry.

ACKNOWLEDGMENTS

The work was carried out at the Production Technology Centre at University West, Sweden, and at in co-production with our company network, and supported by the Swedish Knowledge Foundation. Their support is gratefully acknowledged.

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