Action Design Research: Design of e-WIL for the Manufacturing Industry

Full paper

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Abstract

This paper reports on a design process of e-learning courses for competence development of experienced employees in the manufacturing industry. Through a cross-organizational collaborative action design research project the aim was to design e-learning courses at university level to support work-integrated learning. Two design- and learning cycles were evaluated over two years. The first cycle identified challenges that were applied to a pilot course in Industrial automation. From evaluation of this course we derived design principles applied to two further courses in Machining and Negotiation skills. The results from our empirical data suggest general principles as competence mapping work, collaborative manufacturing e-WIL cases and interactive learning technologies for design of e-WIL courses as boundary crossing activities to reach transformative learning integrated in the manufacturing industry.

Introduction

This paper reports on a design process of e-learning courses for competence development of experienced employees in the manufacturing industry. The design work is part of a collaborative action design research (ADR) project between industry companies and the production technology center (PTC) at University West in Sweden.

The manufacturing industry is facing rapid technology changes in a global competitive market (www.asce.org/raisethebar). Shorter product cycles, reduced production time and available expert knowledge are key issues in a competitive branch. A prerequisite is therefore to continuously advance skilled employees. Manufacturing knowledge changes rapidly and affect companies' performance, knowledge acquisition and learning time. It is not only an issue for the individual worker, nor is it solely a matter for the HR or education department, but a responsibility for the whole organization (Lindgren et al. 2004). Moreover, continuous competence development is hard to accomplish for a single company and collaborations outside the own organization with higher education institutions can increase the potential of gaining knowledge through e-learning and flexible education.

As competence development today is progressively adapting to e-learning technologies and more flexible educational forms, new modes of learning anywhere and anytime offer employees to take control of their own learning (Beetham 2013; Drlik and Skalka 2011). Higher education institutions traditionally offer distance education to single learners, but usually not targeted to industry needs. Neither is it common practice for industry companies to search for e-learning courses on university level. Consequently, competence development initiatives with cross-organization collaborations through custom-made e-learning courses render multiple challenges, e.g. different learning cultures, competence mapping, low level of employees' academic level, low experience of e-learning technologies, and transition of learning outcome integrated in the workplace for an effective manufacturing (Akkerman and Bakker 2011).

Given the situation of industries competence demands, a collaborative action and design research project between 15 industry companies and PTC as a joint venture, was initiated in 2013. The shared goal was to design e-learning courses in engineering at university level to support work-integrated learning (WIL).

WIL is described as an umbrella term including different approaches and strategies concerning learning through integration of theory and practice of work within a purposefully designed curriculum (Patrik et al. 2008). Collaborative and co-creative dialogs concerning knowledge needs and learning content were delineated as implications for design of e-WIL throughout the project. Over a period of 24 months (2013-2015) the PTC project group collaborated in a network with stakeholders from the 15 industry companies, both large companies and SMEs, within the aerospace and automotive sectors. The reciprocal research question agreed upon was: *How can e-learning courses be designed to support competence development and work-integrated learning?*

In the next section the concept of e-learning, WIL and engineering knowledge is described. Then the ADR methodology applied to the whole research project is outlined. The data collection consider in particular design actions around three courses applied to the ADR cyclical design loops. Through analysis of the pilot course (cycle one) we describe design challenges and derive design principles, applied to two further courses. We conclude our findings and learning implications, and suggest general principles for design of e-WIL courses.

The concept of e-WIL

The concept of e-learning is imprecisely defined and has been debated by e-learning designers, researchers, educational institutions and users since the rapid digitalization made it possible to meet learners anywhere and anytime (Drlik and Skalka 2011; Lahn, 2004; Michaliski 2013). With internet and the digitalization of knowledge and learning it is no longer a question of what can be designed, but rather of how and for whom. Gaining a collective view of e-learning is a complex and heterogeneous task considering the IT artifact itself, the in-built didactics in learning content and functionalities in the learning platform. Moreover, how technology is contextualized in relation to both organizational settings and to other competence activities is central for learning. Given this diversity, we initially explored how industry companies experienced e-learning technologies and competence development among their employees (Hattinger et al. 2014). To understand the multiplicity of design and use of e-learning from a university practice on the one hand and from a workplace perspective on the other, we shortly describe these two traditions.

Swedish universities traditionally distribute distance education courses in various digital forms mainly to meet *individual* learners on both graduate levels and for adult learning. Courses are often designed for communication and delivery of course content as text and videos through a learning management systems (LMS), often combined with web-meetings systems, weblogs and other types of social media. These courses are administrated as regular academic courses and target part time workers and learners geographically dispersed and not campus students. As university courses they bear traditions of academic values, theoretical knowledge views, communicative skills, strict curriculums, assessment rules etc. (Kahiigi et al. 2008; Simões 2013; Singh and Hardaker 2014).

The mainstream of e-learning in the workplace organization, traditionally focus on training and successful implementation of technical and functional aspects of e-learning, not considering underlying social and pedagogical aspects (Govindasamy 2002; Lahn 2004; Michalski 2013). E-learning aim at enhancing learning based on information technology to deliver and support learning content (Violante and Vezzetti 2012). Courses are usually short instructions and aim to educate employees about e.g. methods and ethics, quality standards and security rules. This type of e-learning, incorporated in some kind of educational platform and situated in the workplace, i.e. learning through instruction, is debated as having small effects on in-depth learning because other conditions may cause dilemmas in the work situation as lack of management support, low learning culture and technology maturity (Lahn, 2004; Michalski 2013). Therefore, a more complex understanding of learning integrated in the workplace ought to be considered when designing for competence development attaining knowledge development and learning (Boud et al. 2003; Cheng 2011; Fuller et al. 2007; Govindasamy 2002; Lahn, 2004; Michalski 2013; Servage 2005; Tavangarian et al. 2004).

Another complexity, when designing e-learning in a manufacturing context is the nature of engineering knowledge as both interdisciplinary, broad and deep. Manufacturing technology handles concurrent and complex phenomenon and development of modeling and simulation (Malmsköld 2012). The techniques and skills required to master underlying theories, are often limited in the industry, while experience-based expertise and practical skills are often high. Also e-learning training is mostly focused on handling machines, though these systems do not always succeed in real problem solving and learning because they lack design of interaction with other learners and/or teachers (Singh and Hardaker 2014).

Consequently, using traditional university distance education courses is not enough for industry knowledge progress, nor are e-learning tools offered for company education. Given the diversity of adoption and diffusion of e-learning based on either an individualist (micro) or structuralist (macro) perspective is neither a prospective model for learning. Instead, we need to further more examine learning approaches and design as an *integrative process* between different learning cultures (higher education and industry organizations), and co-ordination of individual and workplace learning (Singh and Hardaker 2014).

Given this complexity, the design challenge is to both *integrate* workplace engineering knowledge needs with the university academic learning traditions into work-integrated e-learning (e-WIL) courses. We suggest a course design that emphasize both theory and practice, target for groups of learners mixed with on-place lectures (at PTC) and e-learning technologies available in the workplace or at home (or mobile). This includes *interaction and learning technologies* for distribution and communication of learning content as LMS, web-meeting systems, discussion forums, chat, social media etc. and, *digital learning content* as instructional video, tutorial guides, wikis, 3D-applications, etc.

Before presenting challenges in the project and the design cycles of three courses, we introduce the ADR methodology and the data collection and analysis.

The ADR methodology

This article reports on an ADR project combining action research (AR) and design science research (DR), where the aim is to both seek practical relevance and academic rigor (Lindgren et al. 2004; Rogerson and Scott 2013; Sein et al. 2011). We aim to provide practical solutions for the work practice and at the same time address research questions and therefore use these two research approaches in combination.

Historically DR has been one major approach in IS research focusing on evaluation and design of IT artifacts, meaning that the main core of the research is the IT artifact itself and how to design, build and evaluate "it". However, a consequence of this focus on the artifact itself is the lack of considerations from the organizational contexts influencing the design, evaluation and use in practice. Another stream of research is AR involves active participation of the researchers that affects various forms of social action. Hence, action research aims to solve practical problems while expanding the scientific field (Baskerville and Myers 2004). Even with advancement of the design research, scholars from the action research tradition have stressed new approaches to develop the IS field (Mathiassen 2002, Mumford 2001).

Today the argumentation enclose whether to use AR and DR as *similar*, as *combined* or as *different* approaches and the consequences within the IS research community. Some scholars discuss similarities (Cole et al. 2005; Järvinen 2007; Lee 2007). Other argues for combinations to seek for both practical relevance and academic rigor (Lingren et al. 2004; Sein et al. 2011). The way these researchers have addressed DR and AR in relation, is not without critique of this easiness of similarities and differences from those meaning that these approaches are incompatible if the differences are not thoroughly addressed, e.g. how results are analyzed and generalized (Iivari 2009; McKay and Marshall, 2001).

Sein et al. (2011) present an ADR method with principles attempting to overcome the diversity. They argue for a synthesis of DR and AR to build innovative IT artifacts offering a solution and learning from organizational intervention while solving a problematic situation.

Furthermore, they view the IT artifact as an ensemble in order to first deal with a problem situation in the organizational context and second to construct and evaluate an IT artifact that aim to solve work-based problems. To overcome the critiques of AR´s ability to generalize results they argue for an instantiation of a class of problem being generalized into a higher class of problem, and if researchers seek generalized outcome, they should follow the suggested principles in their ADR method (Sein et al. 2011).

Data collection and analysis

This overall research study is an ongoing longitudinal research project started in 2013 and today 24 month later we report on actions and challenges in the design process with main focus on the three realized courses. Table 1, below summarize collaborative actions among stakeholders and documentation and research data collection. We have applied the ADR method by Sein et al. (2011) consisting of four main stages, 1) problem formulation, 2) building, intervention and evaluation – BIE, 3) reflection and learning, and 4) formalization of learning. This cyclical method is applied to the overall project and mainly to each of the three academic e-WIL courses (of 2.5 ECTS) in automation (pilot course), machining (Tech Comp) and negotiation skills (Business comp = Bus Comp).

In the following we shortly outline the overall actions and the project work. Thereafter we specifically analyze how features in each of the courses, employ common design principles affecting participants learning.

Project work and initialization

The research approach is qualitative and we used multiple sources for data collection; interviews, seminars, focus groups, course evaluations, questionnaires and observations (Bryman 2012). All actions were continually documented, interviews and focus group meetings audio-taped, and verbatim transcribed and analyzed.

The project is hosted within the research group Production Technology West located at PTC (www.ptw.hv.se). PTC is a manufacturing research center with about 80 employees doing research in automation, machining, welding and thermal spraying. The PTC laboratory is well-quipped with an automation line, multi-task-machines, material labs etc. A project group of 15 participants including the authors as research analysts (informatics and logistics), eight researchers/teachers (engineering and computer science), two ICT pedagogues, one technician, one administrator and the project leader (robotics) manage the project. Up until now approx. 80 participants have joined including the project group, 36 course participants and 29 company managers.

In the initial problem formulation stage we established collaborative relations between regional industry companies and PTC, to explore competence work and abilities to learn as crucial for the knowledge creation and e-learning readiness. Through 16 semi-structured simultaneous interviews with 27 HR and manufacturing managers at 15 industry companies, we gained knowledge of the companies' status of awareness, e-learning maturity, dynamic capability and co-creativity (Hattinger et al. 2014).

Analysis of course data

To define design challenges for the pilot course we collected data from the initial stage through the company seminars and competence mapping work together with results from the teacher study (Hattinger, Spante and Ruijan 2014). The data collection and analysis for each of the realized courses, highlighted in table 1, aimed at collecting data of participants e-learning maturity and former knowledge level, following the process of 1) handing out initial *questionnaire* (course day one), 2) *observations* and *evaluation* of learning content, files and video material distributed including selected LMS, 3) *observations* of web-meetings (Adobe Connect, screen sharing, integrated voice and video, information and application sharing) as discussions, negotiations and lectures between teachers and participants, and 4) a concluding *focus group session* (last course day) with semi-structured questions guided by the two research analysts and bringing in participants view of course content, IT tools, digital instructions, video material, digital communication, WIL projects (cases), examinations and virtual labs.

Base facts from the three questionnaires were analyzed. In short, of 36 participants only three participants dropped out, six participants had a former engineering academic degree (master level) and the remaining a technical high school education. Only six had experience of e-learning courses.

Digital course content, IT functionalities and Adobe Connect-sessions were analyzed and documented and discussed with teachers and in the research group. The audio-taped focus group sessions were transcribed and we used NVivo for content analysis and categorization of data (Bryman, 2012). Results are presented in next section and applied to the ADR method (Sein et al. 2011).

Stage	**Stakeholder**	**Type of action**
		Cycle 1
1. Problem formulation Jan-Jun 2013	HR managers Manufacturing managers	16 interviews with 15 industry participants, 29 respondents
	Managers Network organizations	1 seminar with 7 industry companies and 2 network participants
Aug-Dec 2013	Project group	4 ICT-seminars with teachers, media technicians and researchers, 10-15 participants in each session
	Project group	Frequent collaborative meetings for design of web platform for course marketing and applications Frequent collaborative meetings about design and evaluation of new LMS 5 interviews with teachers as respondents
	Project group Teachers	Frequent meetings for iterative design and implementation of pilot course, 2 teachers as designers
Pilot course (Industrial Automation) Apr-Jun 2014	Course participants Teachers	1 questionnaire, 10 course participants in 3 industry companies
		Continual formative evaluation made by teachers
		1 focus group, summative evaluation and discussions of pilot course with 9 course participants in 2 companies
3. Reflection and Learning May-Oct 2014	Managers Network organizations	1 seminar with about 5 industry companies 2 network participants
	Project group Teachers	Internal meetings with focus on deriving design principles in relation to lessons learned, for up-coming courses
		Cycle 2
2. Building, Intervention and Evaluation - BIE Sep-Dec 2014	Project group	2 ICT-seminars with pedagogical instructors, teachers, media technicians and researchers, 10-15 participants in each session
	Network organizations	1 seminar with 2 network participants and about 20 industry company participants
	Teachers	Iterative working process for revision of course design and study guide. 3 teachers in course Machining and 3 teachers (including one from Machining) in course Negotiation
Course Machining Tech Comp Nov-Dec 2014	Course participants Teachers	1 questionnaire, 13 course participants in 4 industry companies
		Continual formative evaluation made by teachers
		1 seminar and observations in Adobe Connect with, 13 participants
		1 focus group, summative evaluation and discussions of the course with 9 course participants in 2 companies
Course Negotiation Bus Comp Dec 2014 – Jan 2015	Course participants Teachers	1 questionnaire, 13 course participants in 1 industry company
		Continual formative evaluation made by teachers
		1 seminar and observations in Adobe Connect, 13 participants
		1 focus group, summative evaluation and discussions of the course with 13 course participants in 1 company
3. Reflection and Learning Feb 2015	Managers Network organizations Project group Teachers	1 seminar, presentation and discussions on performed courses, with 4 participants in 2 industry companies, 2 network participants and 15 project teachers/project group members
4. Formalization of learning Feb 2015 - forthcoming	Project group Managers	Collaborative actions for design and implementation of DP ver 2. Four courses are planned during spring 2015 (negotiations, security in machine systems, automation and machining)

Table 1. Overview of ADR actions in relation to stakeholders

Design of e-WIL courses

Analyzed results from the data collection of project actions with specific focus of course design and evaluation are described as two iterations using the ADR stages (Sein et al. 2011), see figure 1. While table 1 outlined the stages in a sequence, the figure below shows different stages in a cyclical process between research actions and practice.

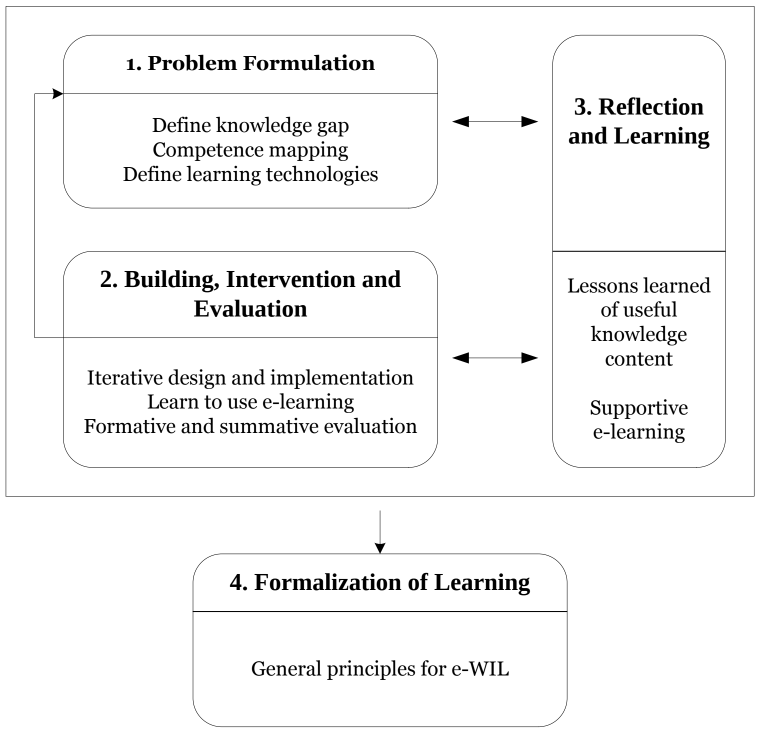

Figure 1. Stages and actions

Stage 1: Problem formulation

Throughout the project, company managers and the PTC project group deliberated challenges of competence work, see table 2.

Challenges	**Goals**
Industries need increased knowledge for effective manufacturing	Competence mapping between university and manufacturing industries
Employees' are skilled with practical experience but lack formal higher education	Higher education courses with both practical and theoretical content

Table 2. Competence challenges

Initiated discussions concerned competence mapping of core engineering knowledge fields and also identification of knowledge levels in relation to university course curriculum. The low level of employees' formal education is problematic as most of them lack formal academic credits, but are skilled with 10-15 years of industry work, often as specialists or experts. Though, the university is not accustomed to validate informal knowledge on master course levels.

Stage 2: BIE - Pilot course cycle one

The co-creative actions described above, resulted in design challenges for the pilot course. The design work is concluded in table 3. These challenges influenced the design of the pilot course in Automation (started in April 2014) and offered as a blended course with five half day lectures and labs at PTC, performed over a 10 weeks period. After each lecture, a home assignment was given. The course material was distributed on the university-LMS. The digital learning material contained four power point presentations and six videos of 5-9 minutes.

Challenges	**Goals**
Authentic assignments and assessment for WIL	Multitude case assignments and laboratory work for WIL
Learning material for classroom communication	Digital and interactive learning content and video
Low e-learning experience for both teachers and employees'	Experienced e-learning users

Table 3. Design challenges

After realization the course was evaluated against the challenges. The following quotes are analyzed from the teacher study, and the focus group session. They show a variation of both challenges and goals.

Challenges

WIL assignments

> Teacher: *"I have cooperation projects with companies, so I can tell stories to the students that might be good for their studies."*

Assessment

> Teacher (programming courses): "*I had a lot of problems with assessment of group assignments in the classroom, because they covered for each other. I wanted to know the specific student problem solving insights, so I wanted them to show it individually in a structured and logical way."*

Learning material

> Participant*: "Both the PLC lab and the Robot system task were good. But they were performed here at PTC. "*
>
> *"The virtual lab was good, learned a lot, but only applicable on the computer at home."*

Goal

Digital and interactive learning content

> Participant*: "The first instructional video was available on the iPad or phone, but later on it was some problems with the streaming server because they had to switch to another system."*
>
> Participant*: "Nice to have videos, they were really good."*

LMS

> Participant*: "There were problems connecting the LMS to the job e-mail. We don't use student mail at my company, but besides that I like the university-LMS …easy to use…".*
>
> Participant*: "Only used it for downloading files and other stuff, not for communication."*

E-learning experience

> Teacher*: "Online education experience, it depends on what you mean? I would say, none. I did some in year 1989, with completely different techniques. Last year… some supervision with a PhD student at Volvo Cars with advanced online tools as WebEx and VMware… but not as teaching for a student group."*

Both teachers and participants have good technical skills but lack e-learning experiences and mental models of its usefulness.

Stage 3: Reflection and learning – Pilot course cycle one

This stage began after the pilot course finished. The different data sources were summarized and challenges for upcoming courses were derived into *design principles (DP) version 1*. All ten participants passed the course and were on an overall level satisfied. Results show that videos and the virtual automation lab supported learning. Participants suggested a shorter period of course time and fewer physical meetings, replaced by digital learning content and/or synchronous web-meetings. Design principles derived from these results are described in table 4.

No	**DP version 1**
1	Competence mapping
2	Design of course content for WIL
3	Design of digital learning content
4	Differentiated use of interactive learning technologies

Table 4. Design principles

DP 1 – Course content mapping

The initial competences study showed industries status of knowledge needs, although this is a continuous and reflective process throughout the project between all parties and therefore an essential repeated design principle. Consequently, it was further discussed:

> Teacher*: "In the end of the pilot course, participants have asked about up-coming courses.*
>
> HR manager: *"There are a number of people that would like to develop their negotiation skills."*

It was decided to start two new courses autumn 2014, respectively in negotiation skills targeted for both technical engineers and purchase staff and machining, an elementary subject in manufacturing engineering.

Stage 2: BIE – Tech-Comp and Bus-Comp cycle two

Design principals version 1 were applied to the two courses; Tech-Comp and Bus-Comp, see figure 2, that shows the overall ADR cyclical process. A general course format was decided with a maximum of 2-3 day meetings at PTC. At least one web-meeting in Adobe Connect was recommended. Both courses were designed over five weeks with introduction day at PTC and ending with a half day examination.

In addition to these general guidelines they were designed in two variants, due to the different knowledge types. In *Tech-Comp*, one additional full day lecture was included, an additional three hours Adobe Connect session with a lecture and group participant presentations. In the *Bus-Comp* the main WIL-assignment was a Harvard-case, a group negation task conducted by discussions among the participants using Adobe Connect and observed and only guided by teachers.

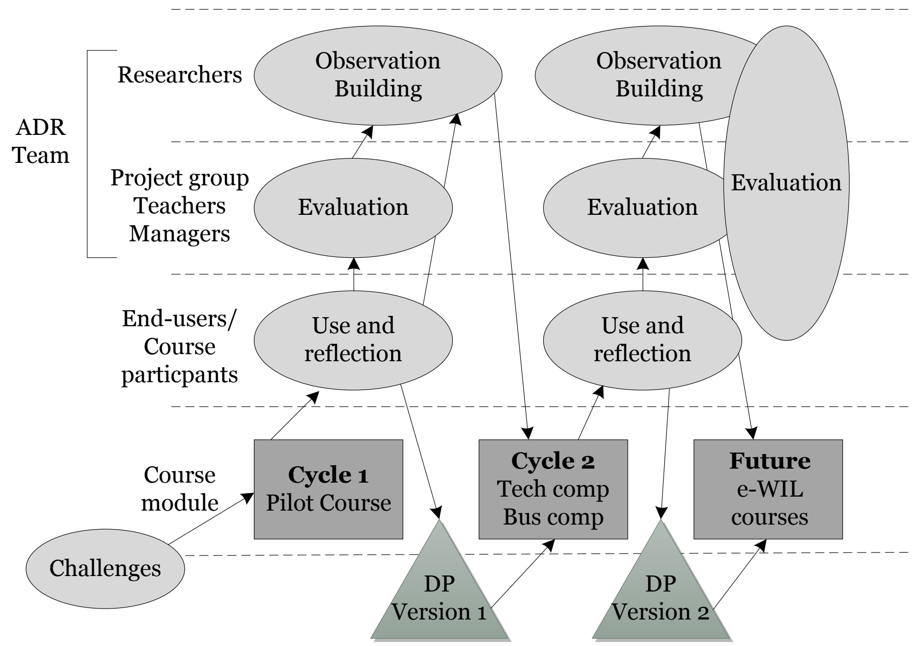

Figure 2. The ADR process

DP 2 – Design of course content for WIL

The design work focused on deriving work-integrated learning topics with strong manufacturing relation and practical-theoretical case assignments on relevant level for experienced practitioners, and also applicable for both large companies and SMEs.

The Tech-Comp contained a turning and milling lab assignment performed by participants in their workplace. One participant from the consultancy company describes problems accomplishing this task:

> *"First I had problems with the turning task, not finding any time or equipment, and then we were given another task of milling on top of it! I kind of lost it there. At that time I was working as consultant in another company."*

Participants preferred using PTC equipment, but there were suggestions of collaboration among participants and to share equipment for the tests.

In the *Bus-Comp* participants were given an assignment to produce a film showing a role play as a realistic negotiation situation. The task aimed at participants could analyze negotiations in relation to both theory and practice. Initially this task was questioned.

> Participant: *"In the beginning it was hard to understand the task, I mean to make a film? I don´t have photo equipment or earlier experience of that. The instructions were very fuzzy."*

This statement shows that there was a lack of experience using media technologies for either use of cell phone or other free ware.

DP 3 – Design of digital learning content

Though there were many ideas on instructional videos, time constraints and lack of experience to plan and produce interactive learning content with e.g. Camtasia resulted in teachers not producing any instructional videos in the design cycle 2. Instead, efforts were laid on production of power point´s applied to the target group. In the *Tech-Comp* teachers, with least digital learning content, they only referred to some Internet videos.

Participant: *"I also joined the automation course, and those videos were good. I lack it in this course."*

Interviewer: *"So more videos?"*

Participant: *"Yes, but as a part of the course, first I want to watch the video and then we [participants] can discuss it in a mutual chat. But we first need questions to discuss, initially handed out from the teacher."*

DP 4 - Differentiated use of interactive learning technologies

The Tech-Comp was based on three whole day lectures and the use of content learning technologies was limited, resulting in a more traditional campus course with only elements of e-learning. Due to time constraints the university-LMS was not used, instead Drop-box for distribution of files was chosen. Though, Adobe Connect was used twice for web-meetings with lectures and discussions.

Drop-box

"It was not arranged with university-LMS, got Drop-box instead."

"We cannot upload our files, a bit tricky."

Adobe Connect

"We took part in the testing, but then I think that our own network and fire walls interfered."

"Generally good to meet in this way… one actually have to take and meet in a new form and not travel."

"It was easier to sit at home and not at the company, there we cannot use the camera."

"I had to leave the office so I switched to the iPhone, and it worked perfectly!"

Participants felt that Drop-box was not satisfactory. Web-meetings through Adobe Connect showed initial technical problems, but eventually all participants liked it as a useful pedagogical tool.

In the Bus-Comp they used the university-LMS and they met in Adobe Connect for a half day negotiation case seminar (role play). Participants controlled the role play, and were divided in two groups in two web-meeting rooms. Depending on the participants' previous experience of the system, the outcome differed. Teachers were observing the case discussions and gave formative feedback at the end.

University-LMS

"All materials weren't uploaded and we couldn´t upload the films for the examination? Also, I didn´t receive all lecture material from the teacher in time."

"User friendly when it works."

Adobe Connect

"In the conference room at our company it did not work and I do not know why."

"I think that we could have practiced more in this system."

The quotes show that teachers did not plan delivery of the course material in time through a LMS. The negation task in Adobe Connect was hard, though some participants were gradually more positive to the use.

Stage 3: Reflection and learning – cycle 2

Here we summarized results from the three courses and especially the last two that applied to DP version one, thoroughly analyzed from a course participant perspective.

On an overall level the result is satisfactory viewing the low level of e-learning experiences among both teachers and participants. The low level of formal education is challenging because the university have rules for enrolling students, even if participants is considered well skilled. Collaboration for *competence mapping* (DP1) is time consuming, but also reciprocal. The design concept emphasized a framework of *interactive learning technologies* (DP4) for distribution of learning content and communication/interaction. This shows a broad variation of design and use. The pilot course did not use Adobe Connect or any other interactive social media, but use the University-LMS. The Tech-Comp used Adobe Connect for planned meetings, but no other interactive social media or LMS. Consequently, digital interaction was low. The Bus-Comp was more interactive, but driven by participants own use of communication tools. Consequently, all courses need to implement more interactive social media.

Producing digital learning content (DP3) is time consuming and the pilot course was outstanding with six videos and a virtual lab. The Tech-Comp needs more digital learning material and to reduce the daily lecture time. The subject of negotiation in the Bus-Comp is not pure engineering knowledge, thus interactions should be emphasized rather than design of video material. Virtualization of laboratory work can strengthen both the pilot course and Tech-Comp. All courses, though, show a high variation of creative approaches on WIL learning content (DP2), but performed in traditional formats. WIL assignments need to be virtualized and digitalized in the future.

Stage 4: Formalization of learning

This stage concluded the design and realization stages during autumn 2014. Summarized findings were presented and discussed at a company seminar in February 2015. Further actions for up-coming period were decided; design of new learning technologies and continual production of digital learning content. Discussions and planning of further courses took place, and one suggestion was to repeat the three courses and offer two new; machine security and simulation based FEM. Given this mutual request the need for a formalized process with general DP version two were highlighted. This process is discussed below.

Discussion on formalization of learning

Prior research on competence development in the workplace emphasize a complex understanding of the learning context when designing for e-learning initiatives (Boud et al. 2003; Cheng 2011; Fuller et al. 2007; Govindasamy 2002; Lahn 2004; Michalski 2013; Servage 2005; Tavangarian et al. 2004). To understand the engineering practice, recognize learning challenges and create constructive and digital courses is important when designing for knowledge creation and learning in this context (Capobianco et al. 2006). However, there is limited research on action design research on work-integrated e-learning initiatives especially when universities collaborate with manufacturing companies. Given this situation the aim was to design e-learning courses to support WIL for manufacturing companies. This dual approach of cross-organizational collaboration is applicable to an action design research approach that expands the scientific knowledge (Baskerville and Myers 2004; Sein et al. 2011). It supports a more holistic and engaged view on design compared to traditional DR (Åkesson et al. 2010; Sein et al. 2013).

Consequently, we performed two design cycles in collaboration with stakeholders. The first cycle identified challenges and a pilot course started. Lessons learned were derived into design principles version 1, see table 5. In the second cycle the principles were applied to the courses Tech-Comp and Bus-Comp. During this cyclic process a close collaboration with company managers and course participants, influenced the process through different roles as informants and co-producers of knowledge. Throughout the action process we viewed WIL as socially constructed, i.e. learning is embedded in social practice, with membership and identity and is therefore mutually dependent on all participants. This accentuates a reciprocal knowledge creation process that is co-constructive (Wenger 1998; Mills 2011).

Based on earlier design, we define the design principles version 2 and consider them as the general design principles for future e-WIL courses, see table 5. The *competence mapping* work is a general principle that is an ongoing and integrative process between stakeholders to target core competences. Without this ongoing process no learning initiatives will take place. *Collaborative manufacturing e-WIL cases* involves digital learning content based on real cases with a participative and co-constructive view of WIL. *Interactive learning technologies* means to design courses that both have interactive and mediated course content and are distributed through a learning platform that emphasize communication and discussions

Challenges	Goals	DP ver 1	DP ver 2
Industries need increased knowledge for effective manufacturing	Competence mapping between university and manufacturing industries	Competence mapping	Competence mapping
Employees' are skilled with practical experience but lack formal higher education	Higher education courses with both practical and theoretical content		
Authentic assignments and assessment for WIL	Multitude case assignments and laboratory work for WIL	Design of course content for WIL	Collaborative manufacturing e-WIL cases
Learning material for classroom communication	Digital and interactive learning content and video	Design of digital learning content	
Low e-learning experience for both teachers and employees'	Experienced e-learning users	Differentiated use of interactive learning technologies	Interactive learning technologies

Table 5. Overview of challenges, goals, DPs ver 1 and DPs ver 2

Conclusion

The actions completed and researched are valuable for development of cross boundary actions combining the engineering field with work-integrated learning activities (Johri and Olds 2011). We derived design principles in two cycles focusing specifically on e-learning courses and suggest that design principles version 2 are generally applicable to be implemented in other fields than specifically in engineering (i.e. Tech-Comp vs Bus-Comp). By using university knowledge and industry experiences we have illustrated that the participating stakeholders can co-construct mutual work-integrated learning actions emphasizing both practical manufacturing knowledge and theoretical relevance. Through this cross-organizational collaboration with joint meetings and courses, two cultures meet and new knowledge insights progress. This is due to time given for reflections and discussions on the mutual practices in relation to new knowledge. Different learning levels and learning fields are debriefed and negotiated through new types of e-learning technologies as boundary objects that give new opportunities for new learning but can cause imbalance if technology does not work as expected. Even if there is a need for further development the results show a broad interpretation and usefulness of courses and in the collaborative actions.

The results from our empirical data suggest general principles for design of e-WIL courses as part of collaborative actions aiming to develop knowledge creation in industry organization and in higher education as boundary crossing activities for transformative learning (Akkerman and Bakker 2011). To reach transformative learning integrated in the manufacturing companies need further studies. We recommend research on how learning actions are integrated and transformed in the workplaces to strengthen co-constructive actions leading to innovative learning integrated in the workplace.

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