Chapter

Knotworking as an Analytical Tool for Designing E-Learning While Targeting Industry Competence Needs

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Abstract

This chapter outlines challenges and opportunities for teachers in higher education in their design work of e-learning courses targeting practitioner's competence development of production technology knowledge. Teachers are challenged to develop up-to-date learning material and digitize learning tasks such as virtual labs and machine-related cases that align to workplace knowledge needs. Design work used for campus education is argued to be insufficient to meet e-learning education while targeting industry competence requirements. Teachers and practitioners are in a transformative process when they engage in mutual design work that both encompass a new e-learning situation, and a new target group of experienced practitioners and workplace demands within smart manufacturing. The theoretical concept knotworking, is applied to shed light on the complexity of designing courses for work-integrated e-learning aiming to enhance professional competences. Knotworking refers to tying, untying, and retying together seemingly separate threads of activity. Based on a longitudinal competence development project, this chapter analyzes considerations of an e-learning design practice through the knotworking concept for understanding learning and practices across professional boundaries.

Keywords: e-learning design, professional competence, work-integrated learning, knotworking, manufacturing industry

1. Introduction

University teachers' efforts and activities of developing blended e-learning courses for professional competence development in manufacturing industry pose potentials but causes also challenges for the university, the teaching practice, and the practitioners. In this chapter these transformative efforts have been defined as design work. The complexity of planning and designing of e-learning courses has been discussed from the university teacher's perspective for meeting experienced industry practitioners need of work-integrated learning.

The potential of blended e-learning is claimed to support learning that is more active, participatory, personalized, flexible, and inclusive towards today's diverse learning needs [1–3]. Blended e-learning courses offer a formal system for arranging and constructing new collaborations and learning between teachers and practitioners in which they can integrate organizational, social and individual perspectives for mutual knowledge development [4]. However, designing for new modes of e-learning targeting industry knowledge needs are forcing teachers' work into a changed pedagogical and didactical practice that pushes them into unfolding new learning strategies and to find an applicable course blend of digitized learning material and new communicative strategies outside the class room [5–8]. Arranging for such learning events includes challenges to define a qualitative mix of on-line time combined with spaces of physical effective meetings and defining knowledge content that matches the workplace demands. Altogether these challenges impact the university traditional routines and teacher's knowledge mediation and hence design work and implementation, hence their design practice [2, 9].

The manufacturing industry is constantly challenged by the digital transformation of the engineering work [10] with an increased need of industrial automation and robotics [11, 12], interconnected machines and big data analytics [13], and new production systems [14] put future professionals under continuous reconstruction [15, 16]. Industry professionals need to be competitive and keep up to industry companies efficiency paradigm, and pressured to strengthen and update their knowledge and skills to meet a globalized production [12]. Consequently, learning to become and stay as a competent expert for an entire working life tends to be harder for professionals [16–18].

Given this situation, engineering professionals continuously seek for new knowledge and learning as an integrated part of work, here described as work-integrated e-learning labelled e-WIL [19]. This means knowledge that will further strengthening their industry experiences combined with new theoretical knowledge. Given these potentials and challenges of long-term transformations call for universities to plan, implement and evaluate competence efforts that meet the industry practice in a whole new way. Earlier studies have emphasized the need to further investigate e-learning across professional boundaries in manufacturing organizational domains and communities [20]. Furthermore, it has been shown that designing for learning across such boundaries is hard, therefore it is here argued for a more close and detailed analysis of how to design to actually plan and implement courses for work-integrated e-learning. Professionals are continuously balancing between individual and mutual goals pressured of their obligations to achieve organizational purposeful objectives and results.

To shed light on the professionals (teachers and practitioners) design work, the theoretical concept knotworking [21] was used as an analytical tool to rethink the design work towards more collaborative activities of professionals temporal teamwork. Knotworking refers to tying, untying, and retying together seemingly separate threads of activity. Hence, the purpose of knotworking is to address professionals innovative and creative ideas and to grasp their inner thoughts and actions in a process of e-learning design. This chapter aims to explore professionals' knowledge discussions in forms of knotworking through the cultural historical activity theory, CHAT [22, 23].

To grasp professionals' involvement and interaction in the design work of e-learning courses, an effort has been made to analyze professionals' specific experiences, their identification, and coordination activities towards transformative efforts. Two studies were carried out within the ProdEx, a longitudinal competence development project, with duration between the year 2013 until 2020 [20]. The project was focusing on competence development within production technology knowledge targeting practitioners in manufacturing industry. In this chapter, a re-analysis of the teachers' and practitioners' experiences has been done by applying the knotworking concept following these two research questions:

RQ1: How can knotworking expand a new e-learning design practice for work-integrated learning?

RQ2: What can be learnt on a systemic level from e-learning design work when applying knotworking as an analytical concept?

2. The context of the research

2.1 The ProdEx project

The ProdEx project (Expert in Production Technology) was initiated as a collaboration between one university in West Sweden together with regional manufacturing industry companies in 2013. It has been ongoing for seven years and will formally end in December 2020. ProdEx will however continue as a regular competence program at the university with courses designed targeting industry knowledge needs. The overall project aim is co-production of competence activities for university-industry stakeholders to strengthen industry practitioner's expert competences. Today the project comprises a network of about 40 different industry companies within the automotive and aerospace sector. ProdEx runs by a project group that is situated at a Production Technology Centre (PTC), which is a well-equipped research laboratory with an automation laboratory, multi-task CNC machines, a material laboratory, etc. PTC is affiliated to the university engineering department.

The university project group consists of action researchers, information and communication pedagogues, IT technicians, administrators, and program managers. Representatives from the project group continuously participate in meetings and co-production activities with the industry stakeholders, around competence mapping of knowledge needs and definition of learning content. Cross-boundary activities topics also concern the design practice of evaluating e-learning design technologies and learning forms towards developing professional skills for a future digitalized industrial work practice.

The teachers are also conducting research projects together with many of the industry companies that takes part within the project. The initial courses in 2014, were designed in action design research cycles on an academic master's degree level [24]. Besides, these teachers are regularly teaching campus courses of 7.5 European Credits (ECTS) within the engineering areas such as robotics and automation, cutting processes, sheet metal forming, welding, additive manufacturing, and smart manufacturing etc. With the support of the project they are responsible for the design work of modifying and slicing courses into shorter modules of 2.5 ECTS targeting the industrial instant knowledge needs. Today, in 2020 within the mentioned subject areas, a total of 30 different five-week flexible e-learning courses, each offering 2.5 European Credits (ECTS), have been designed. At the end of the project in 2020, 82 occasions of the courses will have been completed.

2.2 University and industry perspectives on e-learning

Designing courses for competence development on an academic level encompass a dual situation with the industry effectiveness pressure on the one hand, and the blended competence development opportunities offered by the university, on the other [25]. There may be different motives from the two stakeholders' perspectives of the cross-organizational collaboration that presume a productive development. The university aims to strengthening the individual student to learn more, meanwhile the industry aims to increase the efficiency and competitiveness [11].

Colliding interests and conflicts on different systemic levels may occur, rather than foster energetic changes for learning [26]. Hence, cross-organizational collaborations may not per se cause benefits and learning [27] rather needs to be analyzed through its inner activities as power for change [22]. Learning activities with various inner contradictions are however systemic, embedded in history, developing over time, and cannot be studied directly. They rather need to be understood over time and through close collaborations with the actors [28]. How teachers are using learning technologies has been researched in recent years, however essential questions such as teachers' approaches to use learning technologies in course design that integrate practitioners' experiences and the workplace knowledge needs into the design work is relatively scarce [9]. Studies of teachers' professional identities and coordination activities are affecting their e-learning design plans and pedagogical approaches when including practitioners' experience-based and workplace knowledge needs [29]. Industry practitioners need to learn and develop their competences in a constantly changed work practice. For such needs, blended e-learning courses in higher education (HE) offer a flexible way of learning which is adjusted to and integrated in work practice.

Hence, teachers are shifting identities in their professional role when they approach a new target group [30]. Their perceived design challenges, how they identify and frame earlier experiences of e-learning and/or distance education, or maybe lack of experiences affect how their future pedagogical and technological design will be accomplished. Teachers individual's beliefs and ideas have implications on the professional teaching role and in the design work of e-learning courses that aim to involve active participation from the learners (here the practitioners).

Also, practitioners can feel resistance of meeting the academic culture. Teachers are subject matter experts through an academic degree, but now they need to situate and mediate engineering knowledge, targeting a new group of skilled practitioners with workplace experiences. However, if these differences are used wisely, both actors can, despite their differences, can contribute with valuable knowledge in a learning situation. Industry practitioners and engineers traditionally have long experience-based knowledge of handling machines, tools, and systems, rather than theorizing on practical knowledge. They are knowledgeable and often problem-solving oriented. Therefore, it is argued that constructing knowledge together between teachers and researchers, early in the design process [31] will create valuable insights, higher relevance and flexibility in the design of e-WIL courses [24].

2.3 Work-integrated e-learning and engineering knowledge

In the learning literature, there is limited research on learning that includes engineering workplace knowledge built on participant's experiences as knowledge resources, which can be used in blended e-learning courses [32, 33]. Teachers' need to find a learning approach that is more integrative and relational between themselves and the practitioners, which also can be viewed as 'sideways learning' [34]. Other researchers highlight work-integrated learning (WIL) [19, 35], meaning that work and learning is integrated in everyday practices. WIL can be defined as *"an umbrella term for a range of approaches and strategies that integrate theory with the practice of work within a purposefully designed curriculum"* ([19] p. 4). Designing curricula built on 'ways of experiencing' [36] calls for an approach that incorporates expertise from the practitioners' and their workplaces.

However, what is an engineering practice? [37]. In the engineering work environment, products and processes are constantly changing due to increased digitalization, automation, and robotization. There is a continuous need to improve the capabilities in the working process in manufacturing plants [38]. Operators and engineers therefore must both have operational experience and to be up to date on advanced manufacturing knowledge [14, 39]. The continuous reformation of the manufacturing processes requires employees to regularly assess new engineering knowledge and adapt to changes that imply short-term flexibility, instead of long-term perspectives [18]. Besides short-term perspectives, it is hard to find time for education due to time limits (work vs. time to study), and personnel sometimes have limited experiences of e-learning technologies and low management tolerance for taking time off work for studies, etc. [40, 41].

As argued before, teachers need to establish a close collaboration with practitioners in their design work and to incorporate engineering workplace know-how built on practitioners' experiences. However, such activities presume multiple roles of both theoretical depth and practice-based engineering work. They move from a campus situation into a whole new situation of on-line flexible modes with design of for instance practical cases. Practitioners expertise bonds to diverse tasks such as problem solving and everyday hands-on operations of manufacturing systems. Such know-how relates to procedural knowledge and is different from declarative knowledge [42].

Accordingly, teachers' will have to rethink the learning conditions in advance in their design work of e-WIL courses competence development [43]. Hence, to recognize and comprehend the company organization's knowledge base including their culture, traditions, and practical know-how in such design initiatives [44].

3. Knotworking for tying and untying learning activities

Recent year's research on knotworking have emerged as a response to traditional teamwork [21, 45–47]. According to Engeström [21] teams' traditionally means several people gathered to approach a mutual goal and to accomplish a certain work task, however such teams usually lack both context and history. Today, teams are best understood and replaced by forms of fluctuating work in knots, and through knotworking, as a part of a certain context or activities. The notion of knot refers to distributed activities and partially improvised arrangements of collaboration with otherwise loosely connected actors across organizational boundaries.

"It is horizontal and dialogical learning that creates knowledge and transforms the activity by crossing boundaries and tying knots between activity systems operating in divided multi-organizational terrains". ([48], p. 385).

A movement of tying, untying, and retying together seemingly separate threads of activity characterize knotworking ([21], p. 194). Collaborative knotworking shapes and reshapes to local settings and the center is not fixed and coordinated, rather the unstable knot itself needs to be made the focus of analysis [21]. The *knot* of collaborative work is not reducible to any specific individual or organizational entity as the center of control because the *locus of initiative changes* from moment to moment within a knotworking sequence.

Knotworking, and specifically *negotiated knotworking*, can be used to understand the social processes in inter-organizational collaboration of the learning activities [21, 47]. However, knotworking differs from traditional teamwork in the sense that *continuity is connected to the object*, not to the professionals, because the teachers, the practitioners and the initiators of knots can change. Hence, knots can be considered teams because of their changing memberships and the limited time of their existence.

Engeström [23] has defined the first principal of knotworking, meaning the object orientation of an activity. Through knotworking new object orientation might evolve into a new directionality of purposeful meaning ([23] p. 66).

The second principle of knotworking concerns the tool-mediation of human action and activity. For instance, how e-learning technologies tools (video, LMS-systems etc.) are re-meditating information and knowledge between humans. The third principle concerns the mutual constitution of actions and activity. This applies to collective activities, group actions and to the level of co-constructed mutual activities. The fourth principle of knotworking directs to study changes through contradictions. Contradictions are historically accumulated tensions between opposing forces in an activity [34]. Through revisiting historical layered routines in for instance past e-learning design failures and its contradictions, it was possible to re-construct new ways of designing with new technological tools on a systemic level. Applying the knotworking model requires a long-term effort to study and establish new practices across organizational boundaries. It is through temporary groups that tasks are completing in a longitudinal process where the deadline is not fixed, in which mutual co-construction of future solutions are developing into new practices and further challenges.

4. Methodology

During the years 2014–2016 data collection of two research studies took place within the ProdEx project. Study I was conducted from a teacher perspective [30], and the other Study II, was conducted from a practitioner perspective. The data collection of respondents and specific focus from these two studies are outlined in Section 4.1. Section 4.2 is a re-analysis of excerpts from those two studies through the lens of knotworking.

4.1 Studies and data collection

Of the six included research studies conducted within the ProdEx project [20, 49], two studies were selected that in particular take the perspective of the teachers, Study I, and the practitioners, Study II. The original data collection of the two studies are described below. Study I was conducted through teacher interviews during spring 2014 and targeting the five teachers assigned to develop the first e-WIL courses [30]. **Table 1** describes the teachers positions, course subject area and expertise.

The interviews were performed through a thematic interview guide and lasted about one to one and a half hours in duration. They were audio recorded

Position	Subject area (courses)
Associate professor, PhD Industrial Automation	Industrial automation, robotics, programming (PLC, C++), and flexible and virtual manufacturing.
Senior lecturer, PhD Industrial Automation	Industrial automation, electronics, control systems, robotics, and flexible and virtual manufacturing.
Professor Machining, PhD Mechanical Engineering	Manufacturing technology, machining, metal cutting and forming, simulation, and operations management.
Senior lecturer, PhD Mechanical Engineering	Logistics, quality and design, operations management, negotiation skills, robot systems.
Senior lecturer, PhD Mechanical Engineering	Manufacturing technology, electrical engineering, machining, and cutting.

Table 1.
Overview of the five respondents' positions and expertise.

and afterwards transcribed verbatim. Two interviewers were discussing with the respondents (the teachers) in an open dialogue in which alternative knowledge claims were debated throughout the session [50]. There was also a conversational tone and an open-minded approach guided our interest to understand the teachers' interpretations on alignment and representations of an engineering learning practice. The teachers explored how they perceive design challenges, and how they identified and framed earlier experiences of e-learning and/or distance education, or maybe a lack of experiences. They defined their conceptions on design plans for blended e-learning courses targeting industry practitioner's knowledge needs. Also, a focus was on their perceived ideas on work-integrated learning, meaning how to include practitioners' everyday practice into the course situation and how such inclusion could affect the design of real cases, tasks, examinations and blended forms. A content analysis with open coding was conducted and grounded in the data material of the teachers' narratives about their teaching practice. Individual transcripts were compared to find patterns between statements and thereafter categorized (p. 243 [30]).

The practitioner Study II was conducted during 2014–2016 through continuous focus group interview sessions, which were conducted at the end of each course unit. Data from focus group sessions were collected, audio recorded, and participants were taking part in informed consent. Each session took from one hour to one hour and 15 minutes' to perform [20]. The focus group sessions were performed to capture practitioners' course experiences through their ongoing negotiations, methodologically considered as formative interventions [51]. Each session gathered a unique ensemble of practitioners and teachers with the overarching object of strengthening industry knowledge within specific engineering areas. In total 119 participants (practitioners) and 12 focus group sessions were included, see **Table 2**.

The data collection of the study was ongoing for three years and explored the practitioners' perspectives on knowledge construction through the learning activities within the courses. Mainly their reflections, knowledge views and learning trajectory were studied in order to delineate forms and content of mutual knowledge construction on both knowledge content and e-learning design forms. The data analysis focused individuals' expression of their knowledge experiences and the ongoing social interaction between the participants collectively. For this matter, a content analysis was conducted with concepts, unit of analysis, codes, categories, and themes [52]. During the analysis, codes such as learning technologies, pedagogical strategies, web conferencing use, with corresponding sub-codes such as login problems, communication, and interaction, and so on, developed. Furthermore, the analysis captured patterns and traces of new ideas around practitioners' various negotiations that not only concerned e-learning design and technology use, i.e., the cultural tools, but also motives for knowledge development and new learning

Knowledge subjects	Courses	Nr of sessions	Nr of partici-pants
Automation and Robotics	Industrial automation (4) and Machine security in Robotics (1)	5	44
HR and Businesses	Negotiations Skills (3)	3	34
Mechanical Engineering	Machining (3) and Machining with Tribology (1)	4	41
Summary		**12**	**119**

Table 2.
Overview of the focus group sessions, related courses, and number of respondents'.

Actors	Untying	Tying
Teacher perspective	Campus mode versus on-line mode Issues of new e-learning technologies	Designing together with practitioners Designing digitized cases and labs Digitizing learning content Work-integrated learning
Practitioner perspective	Time and routines for e-learning studies as part of work is affecting the work situation Negotiating obstacles to achieve an academic degree	Time and place for qualitative e-learning towards new practices Incorporating business issues for becoming a competent professional in forms of work-integrated learning

Table 3.
Teacher and practitioner perspectives of untying and tying learning activities.

related to their own workplace. In sum, practitioners' different motives for competence development, the overall university support and the company support became an overall categorization.

4.2 Analysis through knotworking

This chapter first asks how knotworking can expand an e-learning design practice for work-integrated learning. Thereafter, it is asked what can be learnt on a systemic level of e-learning design work when applying the knotworking concept on such design practice. Given this, the re-analyzed excerpts from Study I and Study II through the analytical tool knotworking [21] is applied to earlier learning activities to make open problematic solutions, and more readily grasp fluid forms of knowledge exchange and learning between teachers and practitioners.

In particular, these re-interpretations are presented and organized in relation to the knotworking concept to capture the complexity of the identified issues from a teacher perspective (Study I) and a practitioner perspective (Study II), see **Table 3**. First, excerpts from the previous coding processes was re-coded as examples of untying and tying processes. The coding scheme was further developed to categorize interpretations of oral manifestations of untying and tying processes linked to specific demanding situations. Thus, the analysis was both driven by theory-based categories and new categories that emerged from re-interpretations of the transcribed interview materials following the process of systematic combining [53]. The developed coding scheme is presented in **Table 3**.

The analysis in **Table 3**, will further be explored in the result Section 5, in accordance with the coding scheme that developed during the iterative re-analysis.

5. Knotworking as analytical concept in a collaborative design practice

From a learning perspective, knotworking represents an ongoing process that involves the participation of different groups and stakeholders (university and industry). The mix of contributors bring about gaps and de-stabilization of knowledge, practices, and relationships to normal instruction of cross-boundary collaboration to understand and develop both practices [26]. The professional actors must struggle to make sense of identities, coordination activities and creative ideas in unfamiliar situations in colliding activities, as well as in each other expectations. With an activity theory perspective, learning takes place when subjects encounter dilemmas, tensions, and context-bound contradictions in their activity, in this case, the e-learning design work between teachers and practitioners.

The challenges previously presented in the Introduction (Section 1) and in the Research context and background (Section 2), are issues that teachers and practitioners are confronting, summarized as:

1. targeting relevant engineering knowledge through continuous mapping of industry competence needs

2. developing a case-based methodology that stimulate knowledge construction between practitioners and teachers

3. choosing relevant learning technologies and decide on e-learning forms such as number of physical meetings, use of web-conferencing systems, learning management system (LMS) functionalities, etc.

4. meeting experienced industry practitioners need of work-integrated learning, hence intertwining theory with relevant practice for workplace demands of new knowledge

5. understanding how design work is developing over a period of time for meeting both universities and industry needs of competence development

In the results below, tying and untying knots within the e-learning design activities are analyzed from both a teacher and a practitioner perspective. The excerpts are examples of knotworking processes that are negotiated from various levels. For examples problems and solutions regarding decisions on e-learning content for on-line tasks and examinations, experiences of performing such tasks, validity for practitioners to learn and enhance their own (practitioners) everyday knowledge and skills. The object orientation, the tool-mediation, the co-constituted activities and the contradictions [21] are principles of knotworking, which are analyzed in the activities through untying and tying on various levels (micro and mezzo) in which teachers and practitioners actually manifesting their experiences and thoughts.

5.1 Untying: teachers perspectives

Negotiating certain learning situations within the design work is a process of untying identified and experienced issues and to find a new objective.

5.1.1 Campus mode versus on-line mode

One teacher emphasizes physical meetings for interaction: *"… we can push for having at least three meetings here at PTC for discussions and labs with real equipment ….*"

This teacher is untying a problem by departure from habits of a traditional campus teaching mode, towards transformation to an on-line situation. Teachers earlier identities on how to conduct physical labs and to redefine their classroom context into an e-learning context is about finding a balance from one context to another.

5.1.2 Issues of new e-learning technologies

Another teacher within automation, with high software skills, are trying to unfold software issues: "*There is much software, and I think the challenge is how to present the content of the course in a new way.*"

A third teacher argues: *"... technology problems to get connected with industries because of firewalls. Also, we cannot do everything online, we need to meet and discuss according to my experience."*

Both teachers are explaining their anxiety of handling new technologies and the problems are untyed into certain micro-level issues concerning lack of skills and organizational restrictions. These hindrances make them anxious about how to perform qualitative e-learning solutions.

5.2 Tying: teachers perspectives

Processes of how to solve problems, to find models and new content delivery and also combining resources in new way in order to achieve new goals (both student goals and accomplished exams) are processes of tying together separate threads into future solutions.

5.2.1 Designing together with practitioners

This teacher claim that it is important to include practitioners' knowledge:

"... look after what experiences they bring in with their background and if they have examples connected to the course ... based on that, we arrange the assignments."

Another teacher on the same topic: To find ways of explicate and include tacit knowledge is hard: *"There is not a physical explanation on everything they observe. Therefore, we cannot explain everything. So, there is still a phenomenon what a person does that we can't really explain."*

Both excerpts refer to considerations on how to design for or with practitioners in order to grasp their workplace experiences into an e-learning format. This knotworking process of tying suggests that understanding each other practices (university vs. industry) across boundaries are fruitful.

5.2.2 Designing digitized cases and labs

Actual problem solving (during a course task) is trained through authentic labs, earlier referred to as a process of untying in which labs should be conducted in a physical space. Such activities are strongly bound to hands-on actions and therefore become hard to mediate as digital learning content. However, one teachers says, there is a need for a qualified system for 3D graphics: *"So, I think it's good to create a virtual lab ... it requires a very high graphic quality ... then you can do your experiments online. However, we are not even close to that yet."*

In the tying process the teacher is suggesting new solutions into an unknown practice with high-quality graphics systems etc. An innovative solution that will generate satisfied practitioners conducting the course. It is a matter of continuously redefining and thereby shaping boundaries of the teaching role as they come to act in both worlds simultaneously.

5.2.3 Digitizing learning content

One teacher says: *"I think the greatest challenge is to choose which content that must be interactive and to do the separation of other learning material... we do not believe in 45 minutes movies."*

By learning from bad experiences of long video material including all learning material, new ideas are tied into producing short video films and to decide on other tool-mediations for the rest of the learning material in other forms. This is a process of coordination in order to maintain the workflow through intertwining various technologies and pedagogics.

5.2.4 Work-integrated learning

One teacher describes WIL as: "*WIL is two-folded; first to motivate it to the management that knowledge is good, giving specific demands on knowledge that makes you go to business tomorrow. However, for this type of WIL we are planning, when the companies actually buy a course from us, I think they should have a very clear vision, what they should do with the knowledge, and what they want to achieve by educating their staff.*"

This teacher is arguing for how WIL also needs to be included in e-learning, hence designing for e-WIL courses. Tying together the university vision of WIL with blended e-learning targeting and involving industry practitioner's knowledge requirements, is a way of having innovative ideas on how to perform high qualitative design work.

Untying and tying is an on-going process of resolving tensions and dilemmas into tying new solutions and finding good examples to go further with. The old mental models of campus education traditionally do not fit into this new type of practice. The professional teacher identity is grounded in historical traditions of the classroom metaphor in which the teacher also is the expert, and the learner should follow. However, the excerpts above illustrate that such practice is no longer valid in an on-line environment in which involvement of industry professional's know-how needs to be co-constructed.

5.3 Untying: practitioners perspectives

Untying is a process of unfolding problems to further delineate solutions which is illustrated below from the industry practitioners' perspectives with their experiences of conducting e-WIL courses and participating in focus group sessions as part the ProdEx project. They are actively contributing to the design work incorporating their home company requirements together with their individual experience-based know-how of the broad subject area of engineering knowledge.

5.3.1 Time and routines for e-learning studies as part of work is affecting the work situation

This negotiated knotworking of untying concerns the problematic dilemma of the company's dissimilar conditions to allow practitioners to compensate time for studies versus working hours.

Interviewer: Do you need to compensate with work time for this course day?
Operator 1: No, it is more a feeling one has.
Operator 2: What I did not do at work today, I must catch up later.
Operator 3: I need to clock in at the factory every morning…

The operators have different issues for not having time to conduct the studies as they wish. Such dilemmas need to be considered for the teachers when they design how and when certain tasks and examinations could be performed and how it will affect the outcome of a course.

Other untying issues regard how the companies businesses objectives of increased business values are interfering the practitioners when the companies rather view them "as investments" and not emphasize and support their individual learning progress.

Operator 3:…will my company earn money after I participated in this course?
Interviewer: Hmm, the payoff may not occur instantly, what do you mean?

Operator 4: Through a single course, no, but maybe with a series of courses.

Operator 2: But this competence initiative was not intended due to the company to earn money on us, we should increase our knowledge in case of foretoken, or?

Operator 1: Do not say so to me, the purpose was to earn money!

Operator 5: XX, the HR manager said that we should increase our knowledge to develop from operators into service clerks (engineers), we are sitting loose in case of foretoken, and need to broaden our knowledge and get academic degrees.

Operator 6: Of course, the company wants to earn money on us, like with everything else...

The discussion is heating up and everybody is chatting in each other's mouths. This untying of a problematic situation in which various obstacles are negotiated as alleged assumptions are not common to consider in the e-learning design work. The ethical dilemmas encountered here, are mostly uncommon when educating students in traditional campus courses.

5.3.2 Negotiating obstacles to achieve an academic degree

Furthermore, in the same session as above, the operators clearly describe problems of getting an academic degree meanwhile fear to not lose the job.

Operator 1: Yes, but that is also a question of study full-time or not. This course will give you some breadth.

Operator 2: But if the company was really interested of, hell yes, let's get Marcus an education so that he will flourish into being as qualified as possible...?

Operator 1: If such case I would study half time right away, but such time is not even possible...

These two operators are eager to achieve personal development but clearly lack any opportunities to find a possible solution. By untying such dilemmas, they also manifest their fearfulness of not being able to hold on to their job if they don't perform competence development. They are time pressured and hence the course content needs to be up-to-date and designed in a flexible form adjusted to full-time work hours.

5.4 Tying: practitioners perspectives

These excerpts refer to the course design regarding breaking up old teaching routines with less talking's and doings in real life. How are such tying of new solutions and routines developing?

5.4.1 Time and place for qualitative e-learning towards new practices

In this session practitioners suggest using the latest technology of modern equipment to learn for new practices.

Operator M1: But we like to have more meetings here [PTC], so we can run the robots down the machine hall.

Technician 2: More web-based tasks and when we are here [at PTC], we like to run more labs, like those we did today on the final exams. Very nice!

5.4.2 Incorporating business issues for becoming a competent professional in forms of work-integrated learning

The skilled expert operators, liked to help out, and felt they had superior skills in relation to those with an academic degree. The university lacked enough preparations to support those with low experience of practical factory work.

Operator 2: You must have your own machine, the material, and also tools to test. These are the prerequisites, otherwise you cannot solve the task.

Operator 6: However, the benefit was to take an example from the own factory.

Technician 1: But you cannot just walk into the factory and start during ongoing manufacturing…

Again, the real case issues return due to lack of possibilities for all practitioners to perform the real case task. Hence, in this process of tying and re-tying, was emerging by pointing to the industry organizations values of high knowledge and how such knowledge could contribute to others. This was possible through finding own solutions in the real-tasks and to unfold experience-based know-how. Finding well-formulated tasks for real cases within the courses became important input to the teachers.

To summarize. The object of activity was fluent in the knots and the professionals brought in new knowledge through historical experiences and responses to their own doings and organizational culture (university and industry). Negotiations were conducted throughout the mutual design work before and during course implementation, which was captured during teaching and learning activities. Results show how negotiated knotworking *on the boundaries* between university and industry need to be accomplished, because crossing boundaries is not enough. It gives an understanding on how to go further with solutions or best practice for future innovative objectives. By applying the concept of knotworking it was possible to grasp explanations and innovations for a new design practice.

6. Discussion

In this research approach, knotworking was applied to the *teacher study* and the *practitioner study* that connected temporary groups of teachers, practitioners, tasks, and tools across organizational boundaries, to improve learning and knowledge development within production technology. The tying and untying of problems and suggested solutions were knotworking that took part during the course activities and hence described during the sessions. Knotworking that was negotiated in conversations and communicated, were studied from both the teacher and practitioner perspectives and in different time scales. Consequently, grasping such expressed knowledge, was used to give implications for the overall e-learning design process towards a qualitative design practice of e-WIL courses. The illustrated analysis show that knotworking, and specifically negotiated knotworking is prerequisite inter-organizational collaborative activities towards new modes of expanded object of activities. This means to find new forms, content, and constructions for strengthening expert knowledge between theory and practice, in order to open up respective expert knowledge area.

The negotiated knotworking analysis showed how habits and routines (structures) are not working anymore. Rather, the study shows the importance of not transfer old habits into a new on-line community situation that asks for a transformative process to act in a whole new way. By setting aside old structures and rather focus on a more creative e-learning mode of new technologies and content production the professionals are pushed to design differently.

Practitioners actively contributed to the creation of work-integrated e-learning through their own expertise and knowledge into the courses as valuable subject resources. Through negotiated knotworking of untying and tying, co-construction of new e-WIL solutions in various forms emerged.

Recommendations are to design in short cycles of learning activities including planning and implementation of both new e-learning technologies, real-case tasks, interactive pedagogy etc. towards qualitative e-WIL courses.

7. Conclusion

The analysis of the two studies explored a broad variation to further understand the e-learning practices in the design and implementation work of e-WIL courses. Given this, the concept of negotiated knotworking emphasized immediate actions of shared objects of interest as well as longitudinal processes of learning activities.

The chapter argues that knotworking is a concept for capturing creativity and innovation in temporary groups that meet around common challenges, in which everyone needs quick and creative input of both the joint work and the own areas of responsibility. To summarize, the following lessons learnt are outlined:

- Knotworking stimulates *direct uptake* on short-term responses to changing objects of activity through tying, untying, and retying together seemingly separate threads of activity

- Organizing for temporarily teams in order to stimulate shared motives, and sharing knowledge and learning insights outside traditional organizational boundaries are crucial

- Decision making and engagement in new learning practices require stakeholders' (industry-university) abilities of inter-organizational boundary crossing activities

- Actors' (practitioners, teachers) willingness to problem-orientation and curiosity of new technology and knowledge sharing need to be supported

- Universities openness to new learning strategies of theory-practical intertwining, stimulating mutual learning through innovative pedagogy, e.g. case-based and work-integrated cases and tasks should be a priority.

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