Online Learning with Remote-Configured Experiments

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Abstract: This contribution presents a learning scenario in which online learning is connected with live-experiments in mechanical engineering for different manufacturing technologies. The experiments are remote-controlled and monitored by the learner within physical-real laboratories in three European cities. The aim is to design a technical platform including remote controlled, distance-observed experimentation. Research questions are: How to embed remote laboratories into online learning? How do teachers and learners know what they have learned (when students do telemetric experiments)? The paper illustrates the model of experimental learning and evaluation results. An appropriate balance of teaching input, experimental learning activities, and peer-reviewed assessment is necessary for attractive learning environments.

1 Introduction

Teaching and learning are becoming ever more enhanced by Internet-based technologies (e.g., [JKom09]). According to Collins and Halverson [CH09] the net generation asks particularly for online social networks with 'anytime, anywhere' access. Modern day learning systems are more flexible, adaptable to different existing levels of learning strategies, but they are usually controlled by the teacher as well. They often do not implement concepts that embed the whole learning process into the given curriculum and empower the students to manage their own learning. An approach to design technical, social and educational elements together is delivered by the framework of socio-technical systems and networks (e.g., [WM09], [Bo08]) and the participatory design discourse (e.g., [KB98]). [He03] describes an example of learning and teaching in socio-technical environments. One result is that new learning approaches should be situated in a specific context and be embedded within social interactions and didactical frameworks. Reshaping blended and co-located learning requires the analysis and design of social processes, technical systems, and educational methods.

This paper gives an example of online learning in the field of engineering, where the three dimensions of scaffolding – technical, social, and educational principles – are designed, developed, tested and evaluated. With the example of remote laboratories, exploratory learning is connected with Internet-supported distance-controlled, live experimentation in the field of mechanical engineering for different manufacturing technologies. This online learning approach has been designed and evaluated within a European project. The paper presents the model and the results.

2 Learning paradigm

Discussion in higher education is (currently) focused on the shift from the teachers' teaching to the students' learning [BT95]. Promoting concepts for the shift from teacher-centered teaching to student-centered learning concepts are not new, however discussions about didactic and educational learning approaches were given a fresh impetus as new online community platforms emerged (for instance, wikis, blogs, social networking platforms). According to the "shift", the presented approach claims to support teaching and learning differently. It says that a new balance between teaching and learning is essential for supporting creativity and best learning effects. Learning-centered approaches promote a re-orchestration of teaching and learning arrangements where learning is regarded from the learner's perspective. The guided questions for designing are: what is an appropriate balance between teaching objects and learning activities in online environments (Q1), how to make learner-centered learning, or in other words, what is an attractive learning process from the student's perspective? (Q2)

2.1 Exploratory learning – basis for experimental online learning

In this contribution, learning is defined by social constructivism approaches: "learning is an active process of constructing rather than acquiring knowledge and instruction is a process of supporting that construction rather than communicating knowledge" [DC96]. Learning is not simply defined as the transmission of data from one individual to another, but a social process whereby knowledge is co-constructed in a situation within a community of practice ([LW91], [RGM96], [Su87], [Ja10]). Examples for such constructivist learning approaches are case-based or project-based scenarios. An extended concept is the support of linking research in disciplines with students' learning [JBL07]. This model of 'inquiry learning' is based on exploratory learning approaches also known as discovery learning [Br67]. According to [BR04], "exploratory learning is an active process in which a learner (…) finds out and constructs his own meaning". It means learners explore 'something' (e.g., hypothesis, ideas, and results) without having or being given a solution by the teachers. Learners "interact with the world by exploring and manipulating objects, wrestling with questions and controversies, or performing experiments" [Br67]. However, exploratory learning does not mean unguided learning. Exploratory learning concepts encourage the learner to do experiments and to uncover relationships, for example, testing materials with tensile tests. Learners get the opportunity to discover unexpected outcomes by following various learning paths.

Similar to discovery learning, Kolb's "*experiential* learning theory" [KB00] covers four steps: "concrete experiences" (being involved in a situation, doing something), "active experimenting" (testing a theory by making a plan and following it), "reflective observing" (looking at an experience and thinking about it), and "abstract concept-making" (forming theories about why an experience happened the way it did). In this paper **experimental online learning** is defined as combined forms of discovery and experiential learning that takes place within remote laboratories using an online learning platform with Internet access. In doing experimental online learning, a learner creates her own learning path as a 'walk through' modularized learning activities referring to and driven by her knowledge-oriented interests of concrete experiences. S/he designs exploratory research questions, conducts remote experiments, finds answers, makes interpretations, discusses results in the community and finally writes a laboratory-report (there, s/he reshapes theories by reflective activities). The enhanced guided question for designing is: What does attractive experimental online learning look like? (Q3)

2.2 "Learning was social" – online learning in the age of Web 2.0

In a typical one-room schoolhouse one hundred years ago, "learning was social, not didactic", writes John Seely Brown (in [CH09], p. ix). To foster learning as social processes, one approach focuses on communities of practices. From the viewpoint of Digital Natives [Pr01], Technology-Enhanced Learning can support social learning by using new media like Social Networking, Forums or Blogs. Web 2.0 platforms offer new possibilities to easily enable social learning [JKoc09]. The availability of web access from anywhere at any time has made it easier to engage students in learning communities and can also link weakly coupled learners. [Sc02] stresses that e-learning scenarios in higher education need more attractive concepts, e.g., scenarios support problem solving without having any standard solutions. Schank simulates situated e-learning by describing detailed cases from enterprises ('in case of x, what would Mr. Sheffield, 50 years old, production engineer, do?'). The guided questions for designing are: What socio-technical design does experimental learning need? (Q4), how to combine social learning within remote labs (Q5)? In summary, **experimental online learning** needs the following dimensions:

- pedagogical design (e.g., learning walkthrough guiding discovery learning)
- social design (e.g., communication, community)
- technical design (e.g., interfaces to the physical labs),

and an appropriate interplay of all three dimensions.

3 Case study PeTEX

The project PeTEX „Platform for Telemetric Experimentation and eLearning" (2008-2010) designs experimental online learning. The extraordinary component is that teaching and learning arrangements involve interactive live experiments in three laboratories in the fields of forming (e.g., uniaxial tensile tests for characterizing material behavior), cutting (milling processes), and joining (friction stir welding). The physical-real laboratories exist in three European countries; Germany (IUL), Italy (DTMPIG), and Sweden (KTH). PeTEX's objective is to design a prototype that supports experimental planning and test set-ups including interaction, observation and measurement of data. The experiments are remote configured, controlled via a web interface and monitored through video cameras. Interfaces to the remote labs provide the possibility to change input parameters, interact with the running experiment as well as access and analyze the output results. For continuous process monitoring, the equipment is supplemented with synchronized video recording cameras located at different positions and constantly sending instant images of running experiments. In order to be suitable for remote experimentation, where series of experiments can be conducted, a system of a usage time window or of automation is established. One challenge is to implement such Internet-mediated real experiments from almost every computer workstation, and to customize the didactical concept to such an online learning scenario (see technical aspects in more detail in [TPJ10]). Due to the project's interdisciplinary nature, researchers, educational experts, online learning experts, researchers, and in particular the target groups – teachers and students from engineering – have been involved. A virtual interactive online environment supports the learner's analysis about the experimental results. The results obtained from these experiments and observations described by the learner are embedded in the online learning environment. The PeTEX team decided to use Moodle since it offers the integration of modularized learning objects, and is a multilingual, internationally spread Open Source system. It offers the integration of materials and learning activities via internationally recognized interfaces.

4 Method

In recent years, the approach of Design-Based Research (DBR) has emerged [RHO05]. Researchers, working together with educators and teachers, seek to refine learning theories by designing, studying, and refining rich, theory-based innovations in realistic learning environments [WH05].

DBR in practice means combining methods for design as well as data collection and analysis. In the phase of analysis formative evaluation was used to investigate the learning model. Formative evaluation is a type of evaluation which has the purpose of improving something continuously ([RLF04], [WLM97]). In PeTEX, the purpose is to develop and improve online learning with remote labs for engineers. In contrast summative evaluation only focuses on outcomes. Formative evaluation can use any of the techniques which are used in other types of empirical investigations: surveys, interviews, participant observation etc. In the design phase, a modeling method has been applied (adapted from [HLK04]). It ensures that the target group members – teachers and students from engineering – have been involved (for example, discourse of participatory design, e.g. [KB98]. Within several modeling events, the experimental online learning model, visualized via a graphical diagram, has been developed. The members, teachers and students walk *through* the model while anticipating what possible learners will do in the future. This procedure was guided by specific questions, e.g. "what is attractive online learning with remote labs? What does it look like?".

Phases of analysis and design = two-in-one. Since such participatory modeling events integrate activities of different stakeholders, the concepts and the plan for the distributed community mirror their different perspectives. As [Ch87] said, a socio-technical "design is an arena for conflict". The bringing together of different perspectives can lead to conflicts and problems which have to be dealt with to "support congruence" (p. 158). With such modeling meetings, one can handle those conflicts and find appropriate solutions. So, DBR is helpful for designers, target group members and their needs since it helps them to understand the group for whom the learning processes are being designed. Since PeTEX involved possible future learners, the process of designing and evaluating took place simultaneously. The target group discussed experimental learning processes; they designed collaboratively-constructed the model and evaluated it at the same time within several modeling meetings. Both were guided via specific research and development questions (see above). In addition, PeTEX also fixed two workshops with external experts as an extended part of the formative evaluation (see table 1). In the PeTEX case, seven meetings for data collection, analysis and development in different social modes were conducted (cf. table 1). The collection of qualitative data took place in group discussions which were recorded by audio and video. Notes were taken by an observer and later analyzed using open coding [Br08].

Phases	**When**	**Participants**	**Activities/ Outcomes**
Kickoff	Jan 2009 2 days	• Teachers from engineering from three European countries: 4 IUL, 1 KTH, 3 DTMPIG • Educational experts 2 • Online learning expert 1 • Moderator 1	• Introducing DBR, Modeling method • Group clarified conditions for conducting modeling meetings (e.g., how many meetings, experts, location)
Modeling Meeting 1	March 2009 2 days	• Teachers from engineering from three European countries 3 IUL, 1 KTH, 1 DTMPIG • Educational experts 2 • Online learning expert 1 • Modeling moderator 1	Start modeling with guided questions Q 1: "Imagine, you are a student at the Faculty of Production Engineering. What should PeTEX do to *prevent* learning?" First, Team wanted to collect negative factors and bad solutions (moderation method: "see it from the other side"). Then, Q2 wanted to create aspects for attractive learning Q 2: "From student-centered perspective, how should the experiment and environment look and be designed so that the experiments become attractive for participating?" Outcome: collaboratively-constructed model (visualized by a diagram)
Modeling Event 2	April-May 2009	• Modeling moderator 1 • Online learning expert 1	• Aestheticizing the diagram
Modeling Meeting 3	May-June 2009	• Teachers 3 (IUL, DTMPIG, KTH) • Modeling moderator 1 • Online learning expert 1	• Bilateral discussions about refinement and revisions • Outcome: revised diagram visualizing educational, technical, social design
Additional external Evalu-ation 1	June 30th 2009 1 day	• Students 2 • Teachers from engineering 3 IUL, 1 DTMPIG, 1 KTH • Didactic experts 3 (Universities Hagen, Hamburg, Dortmund) • International e-learning 1	• Description of the online learning model with remote labs in online engineering (illustrating the diagram step by step) • Discussions, conclusions, next

Phases	When	Participants	Activities/ Outcomes
		(Frankfurt University) • Industry partners 2 (Faurecia) • Online learning expert 2 • Modeling moderator 1	steps Outcome: feedback about the model, list of recommendations (cf. section 'results')
Modeling Event 4	July-August	• Online learning expert 1 • Modeling moderator 1	• Clustering feedback items • Revising the model in detail • Sending the refined diagram back to the teachers to ask for their agreement and commitment
Modeling Meeting 5	Nov 2009, 2 days	• Teachers from engineering from three European countries • 2 IUL, 2 KTH, 3 DTMPIG • Educational experts 1 HDZ • Online learning expert 1 HDZ • Guests 'remote labs': 2	• Discussion about the proposed feedback items • Developing of implementation standards (technical design) • Planning next evaluation workshops in June 2010

Table 1: Phases of designing (modeling) and data collection/analysis (evaluation)

Further events are the modeling meeting No. 6 in Italy (March 2010), three external evaluation workshops with usability testing including 'thinking aloud method' and questionnaires in June 2010, and finally a meeting with next steps for sustainability.

5 Results

The experimental online learning model was presented in the evaluation workshop in order to get external hints for improvements, confirmations or discussions. One central result is that the experts, consisting of users like students and teachers as well as experts from education, confirmed the whole learning model (figure 1):

- Learners walk *through* the teaching material, learning objects and in particular learning activities (based on Moodle),
- they prepare and conduct remote experiments in production engineering,
- they write a report about the experimentation, its results, upload the report online, and generate a review for another learner's report.

In more detail, the learning walkthrough covers a range of learner activities including preparation of remote experiments, for instance, creating hypotheses before they walk through the remote lab. After the experimentation, learners write a lab-report about "what they have observed, analyzed and learnt". Such an assessment activity, called "learning diary", is supported by peer-reviewing processes within the learning community and feedback given by the teacher. In the case of successful assessment, learners get a certificate.

The experts evaluated the model as being an attractive learning scenario. However, the evaluation experts also gave many hints for improving the learning model in detail with regard to remote experimentation, social design, technical issues, pedagogical design, especially learning modules. Central results are shown in the following sub-sections.

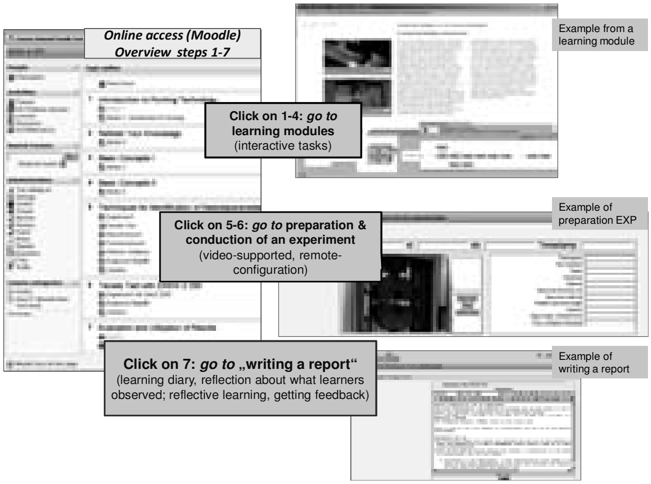

Figure 1: Experimental online learning

5.1 Results for remote experiments (EXP)

The evaluation experts gave many hints for improving the model, particularly the experimental learning elements which is illustrated in table 2. The experts discussed several classified items which were rated from 1 "important" to 5 "less/not important".

Feedback items (given by external experts)	Description and revision of the online learning model	Priority
What is a successful EXP? (e.g., "if the experiment fails" what will the learner learn then?)	It is not only the result but also the right interpretation (of the results; what a learner observes) which is important – then it is successful • Support the learning process: Teacher gives feedback to the learner's interpretation by using Blogs • A learner compares the expert's assessment and his own self-assessment and writes a revision • Who should read the report? Access for all learners? • Integrate rules for writing a report PeTEX needs a time slot for the feedback; how many hours after the EXP does the learner get feedback?	1
Reservation / schedule EXP	A schedule for the experiments should be readable for all participants (awareness, timetable online); it should be possible to book an EXP; learners should observe an "announced EXP".	2
Attractive for teachers?	Make the experiment attractive for the teachers – they use it too	2
How many EXP per person and/or per day?	• 2-4 EXP maximum per day (since too many costs for material) • Create a schedule for EXP that more than one learner can participate/observe (cf. No. 3); creating a PeTEX policy including who may conduct an EXP, how often per day, etc.	3
If PeTEX has money, produce experiments	First produce experiments and technical interfaces, then learning modules, since each teacher makes learning materials slightly different => experiments are the attractive part of the model!	3
Could learners send their "own" material for testing?	• PeTEX can make an offer for the learners to bring their own material (upload it to Moodle – put the offer online!) • Prototype first, but keep in mind this could be a good idea for future steps (could be a critical factor for sustainability)	4

Feedback items (given by external experts)	Description and revision of the online learning model	Priority
How many students?	• How can PeTEX ensure enough learners and a social dynamic within the community? PeTEX learning approach should be embedded into existing curricula at the three European universities • Vision: hundreds of learners	4
Cost of experiments?	When developed, how much is one experiment for the learner? Free for students? Free for employees? PeTEX needs a cost model	4

Table 2: Improvements for designing remote experiments (EXP)

5.2 Social design

The experts' analysis revealed six clusters for improving the social dimension of the model. Four items are classified as less important (at least in the beginning of PeTEX): "add simulations", "combine personal learning environments with PeTEX", and "building intercultural student teams" by using Social Networking Sites like Facebook. In particular, the last aspect was discussed as a vision for PeTEX's future. The following items are important to improve the model:

Who gives feedback to whom in the phases of writing a report? In the phase of reflection (after doing the experiment) each learner writes a report what s/he has observed, analyzed, and checks if the hypothesis (written before doing the experiment) were partly confirmed or rejected. Experts recommend a) students should also get the task to provide a review for another student's report and b) learners should also get feedback from another student c) in addition to the teacher's review. Moreover, experts stressed that the reports and reviews should be put online, for example, using a Blog or similar tools for the report written by the learners (as a basis for assessment). From the experts' viewpoint, learners should have the opportunity to improve or check their own reports. The review process should be guided by questions. So, learners could learn to play different roles (learner and reviewer). A new question came up. Who decides who should write a review for whom? In the beginning of PeTEX, the teacher assigns the learner a report to review. But the vision is that a learner should choose which one s/he wants to review.

One improvement is called "*scenario-based learning*". The experts asked whether the learning model considers different learning activities for different target groups. They stressed the need for clarifying learning outcomes and competencies for different stakeholders, for instance students or lifelong learners, employees from industry. One proposed solution is that PeTEX could create cases or stories based in reality, so called *scenarios*. A bundle of scenarios can be used for different learning activities and different stakeholders with regard to specific levels of difficulty.

5.3 Technical design

The experts delivered five items for the technical design, three of them with priority No. 1. First, the design of the teaching objects in the online platform Moodle was discussed. They suggested to "reduce complexity", "keep it simple", "make technical design also attractive for the teachers", and "create standards for the three remote labs". Second, PeTEX should keep in mind that different access to information for different stakeholders (student, employee) is needed including design for all and accessibility (for example, a button for printing, downloads with standards like PDF). A new question was raised: What should be available for downloading (animations, tests, pictures, text, simulations etc.)? A download should be offered for whatever is possible but the integration of a watermark sign is also needed in case of any copyright problems. The experts suggest making a "Creative Commons License". The third important recommendation covers the technical problem of video proxy inside university networks. PeTEX should get in contact with the computer and infrastructure department to discuss potential problems before the prototype is realized.

Two issues concerning communication aspects were discussed by the experts but were assessed as not so important. The experts proposed the creation of a FAQ (frequently asked questions) covering how to do an experiment technically. Moreover, the experts said that the model needs more ways of communication among the peer-group as well as learners to teachers, for instance a voice chat, or instant messaging with a webcam. This topic was discussed critically. The PeTEX team asked "Why available all the time?" and argued "It could be a problem with technical systems – too much traffic". The group argued that "too many tools could create a 'tool overload' and could cause none of the tools to be used". So, the decision was to reduce ways of communication to only one or two tools ("innovative jams", cf. IBM).

5.4 Pedagogical design

The experts rated the PeTEX learning modules, four categories with priority No. 1 or 2 (very/important), one with priority No. 4 (less important), cf. table 3.

Feedback items (given by experts)	Description and revision of the online learning model	Priority
Standardized framework	One style sheet for the learning modules: "LernBar" provides a frame and structure	1
Modularization of course content	Requirements for structuring course content • Only 2 learning modules in detail per partner • Overall 4-6 learning modules per partner • Each is not longer than 20 minutes!	1
Learning level of complexity	Not too easy but not too much complexity (not too boring, not too difficult), PeTEX decided to integrate three learning levels for identified target groups (what is too easy/complex for them); more active tasks for learners than passive reading, listening or watching sth.; every approx. 10 minutes, an active task is needed (it affects motivation)	1
Reducing time (awareness)	• Do not produce too long learning module (it could be too boring) • Integrate "how much time a learning module takes" (gives orientation, affects motivation), a scale with "percent" or "average estimated time"	2
Open learning paths	Open access, open content? (Needed for sustainability?) Moodle needs a login since the partners have copyright-based material	4

Table 3: Improvements for pedagogical design and learning modules

Standardized framework and structure (priority 1). The experts asked about the guidance "through" the learning processes. How much structure does PeTEX provide, what is good or less good for the learners? The discussions concluded neither too structured nor too open. PeTEX has to find an appropriate balance between formal structures and self-organized informal learning processes. Following the experts' recommendation, the PeTEX team searched for suitable software that also works with Moodle. The e-learning authoring tool "LernBar" (English LearnBar, learnable) was chosen. LernBar [TJP10] is an easy to use system which provides a wide variety of pre-designed templates for e-learning design. The system is adaptable in design and functions according to project needs. Learning modules can be integrated as ims- or scorm-packages into Moodle. LernBar is a system for producing and presenting interactive learning content. Course content is based on HTML and can be enriched with the help of the usual extensions (Adobe Flash, Java applet etc.). LernBar is available at http://www.studiumdigitale.uni-frankfurt.de/et/LernBar/index.html.

Modularization of course content (priority 1). According to the evaluation experts, course modules should be structured in a straight, tailored and progressive way considering the developed rules:

- Providing a general introduction for each course and learning module; introducing current and potential applications; providing the learner with a set of necessary theoretical information (but not overloading)

- Providing the user with open questions and further issues on the subject, which need to be considered in the future, or help to support creative thinking

- Every learning module represents a self-sufficient and stand-alone module dealing with a certain set of arguments without interruptions

Learning level of complexity (priority 1). The experts assessed the learning objects (LO), that a LO needs accurate notions, and a uniform structure: a) *short and clear* (an LO has to explain concepts as clearly as possible); *not too easy but not too much complexity* (too boring or too difficult), for example, long texts are boring to read on the PC screen; animations, pictures, graphics are often clearer and easier to understand; *easy and helpful* (short and accurate definitions of used terms before using them; creating a learning-by-doing environment: an interactive simulator of a technical device and/or a virtual animation are more suitable than a long verbose description) and b) before learners take a course, they need to know which skills are requested and what they will learn; able to allow students a self assessment of acquired skills when LO ends. In particular, the experts recommend integrating more active tasks for learners than passive reading, listening or watching something. Since it affects motivation, every 7 to 10 minutes (after passive reading, listening, or watching something), an active task is needed, for example, drag and drop activities, open questions, multiple-choice answers, creating something.

Reducing time (priority 2). The experts recommended against producing too long learning modules and reducing the time for the learning walkthrough, for instance, each module should be workable in 20 minutes instead of several hours. In addition, the integration of "how much time it takes" could be useful for the learners. This gives the learner more orientation which is also important for motivation. A solution could be to integrate a scale with percent or average of estimated time.

6 Conclusions

This paper illustrated an experimental online learning model including remote laboratories for studies in production engineering. Adapting the Design-Based Research methodology including formative evaluation and modeling methods, the generated model details how to embed remote experiments into teaching and learning processes. The model is useful for supporting learner-centered learning pedagogically, and helpful to clarify what technical and social design issues for a learning scenario like PeTEX's lab didactics are needed (Q4). The model guides the steps of a) learners' activities and b) what the project team implements to get attractive online learning processes. As pointed out in the result section, an appropriate balance between teaching input, learning objects and doing the remote experiments is important. On the one hand, the design of learning modules requires a standardized framework, modularization of course content (that the learner can decide if s/he needs beginner, intermediate or expert level), and a balance between passive reading (listening, watching something) and active learning tasks (every approx. 10 minutes of passive reading/listening/watching an active task has to follow) (Q1). On the other hand, an appropriate balance between learning modules and experiments is needed. Results show that the time for course content should not be longer than preparing, doing experiments and writing the report since telemetric experimentation is the attractive part (Q2). The experiments are in the center of the learning walkthrough. In more detail, a discovery learning model with remote labs in engineering (Q3) needs a special degree of creativity and freedom for learners, so that the learner may create theoretical assumptions about the experiment (in the phase of preparation). A good experimental online learning model also supports failures or 'false assumptions', and the reports written by the learners helps to discover such false friends and new assumptions. Finally, the experimental online learning model shows how to combine exploratory online learning with remote laboratories (Q5).

The overall research question is how to design (develop, introduce, evaluate) technology-enhanced learning successfully and what elements can be designed (general model). According to this study, a "successful design" is defined by the following – or in other words – when developing computer-supported learning, 'success' depends on:

a) First, the degree of structural coupling (degree of interdependency) deals with the complex interconnections of the three elements: technical elements, social/ organizational structures and pedagogical/educational concepts. How closely or loosely are these elements connected? (e.g., is it rather a network or are the elements strong connected and formalized, or flexibly usable?)
    - Technical elements (e.g., learning management systems like Moodle, Blackboard; or social media), for instance, is the technical system easily changeable (by users) or difficult (by external people, software engineers)? Is the social media sufficiently integrated into the pedagogical concept, or is it like

a satellite without connection to the teaching/learning concept? What is the understanding about the technical concept (passive, reactivity, pro-activeness, interactive, transactive, autonomy, etc.)

- Social/organizational elements: forms of communication, roles of teachers/ students; organizational issues
- Educational elements: (non-)formal, informal learning processes, phases of individual/group learning, research-based, problem-, scenario-based learning, support of competence development (which ones?), interconnections between instruction (e.g., rules from teacher) and construction (learners' learning processes) etc.

b) Second: the degree of quality. This degree shows how well the elements interact, for example, the greater the unity among these three elements, the more the users are satisfied and/or the better they share knowledge and co-construction of knowledge takes places, the better they learn.

c) Finally, "a successful design" depends on what the user's role is. Different target groups, people in different roles have different cognitive conceptions of success. Teachers, students, university managers, pedagogical experts, eLearning experts, define it in different ways. A good design includes different views, or at least, supports a common understanding. In addition, different systems (universities, faculties with different cultures) may need broadly similar solutions that can be adapted in the detail.

These three dimensions drive the design and analysis process. In this paper, the design procedure including all three dimensions (technical, educational and social) was illustrated. In the case of PeTEX, such a process was outlined in detail. There are many new questions and improvements that came up via the formative evaluation (see section "results"). To conclude, the model and its procedure is helpful for rethinking and remodeling existing teaching and learning models towards creative life-wide learning cultures.

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