Platform for E-Learning and Telemetric Experimentation (PeTEX)

Tele-Operated Laboratories for Production Engineering Education

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Abstract—The development of tele-operated experimentation and its provision to distance learners opens new dimensions of knowledge acquisition, particularly where experiments are the core elements of engineering education. The finalized EU-funded project PeTEX—Platform for e-Learning and Telemetric Experimentation has developed a prototype of an e-learning platform based on Moodle for the design and implementation of educational and training programs in the field of manufacturing engineering. The principle goal of this project was to establish individual and group-oriented learning for different target groups like students and professional workers within a platform system able to sustain a multi-country learning community. Hence, an educational model was designed which integrates the tele-operated experimentation platform with teaching content and learning activities in order to support a successful learning walkthrough for different target groups.

Engineering education; remote laboratories; live experiments; e-learning; interactive learning platform; online learning; distance learning; research-based learning; scenario-based learning; socio-technical learning

I. INTRODUCTION

Remote laboratories in engineering education are nothing new. According to [1], a wide range of distance learning environments have been developed and deployed over the last decade, particularly in electronics, microelectronics, control engineering and robotics. However, remote “hands on” laboratories in production engineering education, surprisingly, did not yet exist.

The unique aspect of PeTEX—Platform for E-Learning and Telemetric Experimentation is that teaching and learning arrangements involve interactive live experiments through a real-time video-based access into three physical-real laboratories.

The prototype portfolio of the PeTEX environment provides experimental learning for material testing and machining capabilities in the important production engineering fields forming, cutting, and joining [2]. The physical-real laboratories are located in the three European countries of

- Germany (TU Dortmund University, Institute of Forming Technology and Lightweight Construction - IUL),
- Italy (University of Palermo, Department of Mechanical Technology, Production and Management Engineering - DTMPIG), and
- Sweden (Stockholm Technology University, Department of Production Engineering - KTH).

The Center for Research on Higher Education and Faculty Development (TU Dortmund University, HDZ) as fourth partner of the consortium contributed to the development and deployment of the educational model and moderated all collaborative designing processes during project lifetime.

A framework to integrate the technical, educational and social dimensions in the design is provided by the approach of socio-technical systems and networks [3]. Instances of learning and teaching in socio-technical environments provided by the participatory design discourse suggest that new approaches should be situated in a specific context and embedded within social interactions and didactical methods [4], [5].
II. OBJECTIVES OF TELE-OPERATED EXPERIMENTS IN PRODUCTION ENGINEERING

"The use of laboratories is essential for the education in engineering and science related fields at a high qualitative level. Laboratories allow the application and testing of theoretical knowledge in practical learning situations. Active working with experiments and problem solving does help learners to acquire applicable knowledge that can be used in practical situations. That is why courses in the sciences and engineering incorporate laboratory experimentation as an essential part of educating students" [6].

The objective of tele-operated experiments in production engineering during the PeTEX prototype stage is to enable learners

- to effectively carry out material characterization tests with the uniaxial tensile test,
- to weld metal sheets using the innovative technique of friction stir welding (FSW), and
- to set up the appropriate parameters for an effective cutting process as well as to gain knowledge in advanced material and machining process monitoring and optimization (see Fig. 1).

Within the subject of forming, one of the most important tests for material characterization – the uniaxial tensile test – has been adapted for tele-operated usage (see Fig. 2). Furthermore, the aspect of joining has been included in the telemetric experiment for friction stir welding (FSW), a solid-state welding process. Such an approach allows students to remotely control and use a CNC milling machine in order to perform a number of FSW experiments and to test the joints by remotely using a testing machine.

A. Fields of work to apply tele-operated experiments in manufacturing engineering

These experimentation capabilities are deployed in a great variety of academic as well as professional manufacturing engineering’s fields of work, e.g.

- ground-based and advanced research,
- product development,
- manufacturing optimization,
quality control to achieve safe, accurate and efficient materials, and
component and structural testing.

For example in the field of friction stir welding, it should be observed that a greater diffusion of the FSW process and its specific characteristics would have positive effects first of all on the local transportation industries. In this respect, a typical example is given by the Sicilian small and medium enterprises working in the manufacturing of nautical products. Here, joining is a crucial technology to obtain effective hybrid joints (between composite laminates and metallic blanks) but also between lightweight material parts. It should be observed that, today, we are definitively facing a growth of the market of nautical products: on the basis of data from UCINA (Unione Nazionale Cantieri Nautici e Industrie Nautiche ed Affini) it can be stated that, as far as Italy is regarded for instance, the value registered for the Italian production of pleasure crafts for the year 2005 amounted to approx. 2.5 billion Euro, with a 9% increase over the previous year. Today, such industries, with specific reference to the Sicilian environment, are characterized by the application of consolidated know-how and are rarely associated with innovative knowledge, especially as far as manufacturing technologies are concerned.

B. Target Groups and Potential Impacts

According to the UK National Institute of Adult Continuing Education “Workplace Learning is that learning which derives its purpose from the context of employment. It should address the needs and interests of a variety of stakeholders including
employees, potential employees, employers and government. It is a process of learning which will

- enable individuals, employers, and organizations to respond to the changing nature of economic activity;
- contribute to improved efficiency and productivity in employment;
- meet the personal and career development needs of individuals [7];
- respond to new domain specific developments and progresses.

The possibility to run tele-operated experiments will enable workplace learners as well as students not provided with the necessary technological and scientific prerequisites to get a full comprehension of the domain specific material processes, considering both the theoretical point of view and the process potential for actual industrial applications. This will increase the possibility to share valuable resources, like machines or a certain infrastructure with other locations, which do not dispose of these specialties.

### III. Pedagogical Concept

Current discussions in higher education centre on the turn “from teaching to learning” [8]. Concepts promoting the shift from teacher-centered teaching to student-centered learning concepts are nothing new. However, discussions about didactic and educational learning approaches have gained impetus as new community platforms emerged. The new approach claims to support teaching and learning differently. It holds 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 learners’ viewpoint.

In this contribution, learning is defined with the constructivist approach, positing that learning processes are socially constructed: “Learning is an active process of constructing rather than acquiring knowledge and instruction is a process of supporting that construction rather than communicating knowledge” [9]. “Individuals make sense of their own world and everything with which they come in contact by constructing their own representations or models of their experiences” [10]. Learning is not defined as simply the transmission of data from one individual to another, but as a social process whereby knowledge is co-constructed in a situation within a community of practice [11], [12]–as “situated action” [11] within socio-technical networks [14], e.g. at companies’ workplaces and workers’ or students’ ‘home offices’.

#### A. Exploratory, discovery, experiential, and experimental learning

In the presented set-up involving remote laboratories, exploratory learning is based on Internet-supported tele-operated, live experimentation in real-time in the field of mechanical engineering for different manufacturing technologies [15].

According to [16], “exploratory learning is an active process in which a learner (…) finds out and constructs his own meaning”. Learners “… interact with the world by exploring and manipulating objects, wrestling with questions and controversies, or performing experiments” [17]. This means learners explore something (e.g., hypotheses, ideas, and results) without a given narrow solution path. This type of learning model is demonstrated e.g., in case-based or project-based scenarios. An extended concept of this learning model is linking students’ learning with research [17]. This model of
‘inquiry learning’ is based on exploratory learning approaches also known as discovery learning [16].

Similar to discovery learning, Kolb’s “experiential learning theory” [18] 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 the PeTEX project, experimental learning is defined as combined forms of discovery learning and experiential learning.

B. Competence Development as Learning Walkthrough

In this project, learning is conceptualized as a competence development activity. Competences can be achieved by distinguishing and pedagogically structuring the learning environment into knowledge-oriented, skill-oriented, and performance-oriented learning outcomes [19] so that they can provide the basis for learning activities.

The development of competences is designed as a “walk” through modularized learning objects (see Fig. 2), such as instructions (information, knowledge, methods, tools, etc.), learning activities (exploring the tele-operated experiments, data analysis, interpretation, summaries, structuring, questions, answers, etc.), and performance activities (collaboration, collection, producing glossaries, portfolio work, discussions, etc.). Fig. 4 shows the socio-technical structure of the various modularized activities in the learning environment: a learner “walks” through these modularized learning activities, exploring research questions, conducting tele-operated experimentations, finding answers, making interpretations (discovery learning), and, finally, discussing results with peers and writing a report (final assessment).

- The red bar represents the learning community area, where the social software-components for course communication, user-generated content, and resource sharing have been integrated, e.g. a video-conferencing tool with screen-sharing functions, and the Moodle-tools for peer-reviewing (Workshop), forums, blogs, wikis, chat-channels, etc.
- The blue bar represents the Backbone of Instruction, integrating the interactive learning modules. These comprise the necessary theoretical foundations of the three experimental test beds.
The yellow bar represents the three remotely accessed experimental test beds, and the related interactive software interfaces.

This framework facilitates the configuration of walkthroughs as specific training sequences for different levels, from beginner to advanced levels. The latter, more complex self-directed exploratory- and problem-based learning walkthroughs will have comprehensive means of navigating through the entire environment, with the opportunity of interacting with all learning objects, and finding solutions for complex problems.

For the current prototype stage, PeTEX has defined three consecutive learning levels:

- during the testing phase, the beginner-level students will receive a specified guideline for “walking” through the learning environment, and for carrying out a predefined experiment.
- Intermediate-level learners will have to solve a subject-specific real-world scenario, applying the learning objects, and experiments in a self-directed way,
- advanced learners will have to design own research questions. They will have to write a proposal and check it with their supervisor. After his agreement they will get full opportunity carrying out their own experiments.

IV. ONLINE ENVIRONMENT MOODLE

The PeTEX project-team decided to deploy Moodle (“Modular Object-Oriented Dynamic Learning Environment”, available at: [http://moodle.org/](http://moodle.org/)) as the technical and graphical user interface as the basis for the PeTEX-system. Moodle is an online platform integrating learning objects in a highly modularized way. Hence, it facilitates e-learning design for individual as well as community activities in the form of path-oriented and self-directed walkthroughs. The characteristics of Moodle are compatible with the social constructivist approach, which holds that a new balance between teacher-led instructions and learner-led construction must be achieved.

All learning-objects are integrated in, or obtainable via Moodle. Fig. 5 shows the entire Moodle screen with the opened friction stir welding-course, consisting of seven lessons. The foreground shows:

1. an interactive learning module, designed with the e-learning authoring tool “Lernbar” (available at: [http://lernbar.uni-frankfurt.de](http://lernbar.uni-frankfurt.de)),
2. the Moodle-window for conducting the experiments,
3. and the window with Moodle-tools for peer-reviewing (Workshop).

It is also intended to install the openmeeting plug-in to allow for convenient video-conferencing, both within the entire learning-community as well as in the domain-specific courses.

V. CONCLUSION

The effect of this project is merging different types of learning: it provides individual and group oriented knowledge acquisition in the field of manufacturing engineering as well as social and intercultural learning in a multi-country learning community. These processes may bring about a kind of collective identity by means of building up group awareness.
between different target groups within a socio-technical software system. A free access to limited e-learning modules and remote experiments will remain an important incentive for new users. In this way, the complete dissemination of the technical contents will be guaranteed to form a basis for sustainability and continuous development according to the vision of the project.

In general, the obtained and tuned prototype, also on the basis of its modularity concepts, will be further extendable in the future, considering new nodes of the network, i.e. new laboratories connected to the platform, in which further experiments will be carried out, or increasing the level of automation of the considered and presented remote controlled experiments.

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