A remotely accessible solar energy laboratory - A distributed learning experience

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Abstract:

This paper presents the solar energy e-learning laboratory developed at the Higher Technical Institute (HTI) within the framework of the Leonardo da Vinci project MARVEL. MARVEL focuses on experiential based learning-arrangements allowing remote and distributed training with laboratories, workshops and real working-places in the field of mechatronics. As a prototype working example the HTI solar energy laboratory comprises a remotely accessible pilot solar energy conversion plant. A major goal of our approach is to provide the usage of real worlds in virtual learning environments in order to support work-process-oriented and distributed cooperative learning with real-life systems. Telematics, remote and mixed reality techniques are used within a network that includes colleges, industry partners, and national bodies.

1 Introduction

Remote engineering is becoming an import element in engineering education and vocational training. Accordingly there is growing need for new educational concepts, learning media and tools. As a prototype working example we present in this paper the solar energy e-learning laboratory developed at the Higher Technical Institute (HTI) within the framework of the Leonardo da Vinci project MARVEL. MARVEL (Virtual Laboratory in Mechatronics: Access to Remote and Virtual e-Learning) focuses on experiential based learning arrangements allowing remote and distributed working with laboratories, workshops and real working-places in the field of mechatronics to train students in remote engineering [1].

The HTI solar energy e-learning laboratory comprises a pilot solar energy conversion plant which is equipped with all necessary instrumentation and control devices needed for remote access, control, data collection and processing. A major goal of the HTI solar energy e-learning laboratory as well as of the MARVEL project in general is the usage of real worlds in virtual learning environments in order to support work-process-oriented and distributed cooperative learning with real-life systems. Telematics, remote and mixed reality techniques are used cooperatively within a network that includes colleges, industry partners, and national bodies dealing with certification and standardisation issues.

This paper presents one of the learning scenarios, which is developed within the MARVEL project. Firstly, some of the forthcoming trends in the training of remote engineering are described. Secondly, a short overview of the pedagogical concept is given. The HTI solar energy conversion system is then presented, followed by a description of a number of laboratory experiments in the field of solar energy conversion.

2 Training needs in remote engineering

Currently, engineering work is undergoing significant structural changes worldwide. Various studies give evidence for the increasing for telematic-based work environment important in the context of geographically distributed commissioning, installation, maintenance and repair of plant and machinery. Remote engineering, remote maintenance, teleservice or e-maintenance are all catchwords for these novel engineering and management concepts whereby construction and maintenance of plants and machinery are monitored and managed over the Internet [2, 3]. The emergence of these techniques has its roots in the dissemination of mechatronic components - which are nowadays available in almost all modern systems – and the Internet of course. Remote service techniques have benefits for the engineering and plant construction industries as well as for their customers: problems can be diagnosed off site and local engineers can be supported by a central team of remote experts. At the same time, communication between the manufacturer and the user of mechatronic systems is being improved. This helps to reduce service costs while increasing the availability of systems.

As remote engineering becomes increasingly important, there is also a growing need for qualified employees in maintenance departments, in production, in customer service and in other fields [4]. Such demands imply further training for skilled workers, technicians and engineers, which have to acquire qualifications and skills in the following areas:

- installation and using of remote diagnosis and service tools,
- creating and operating communication access points,
- acquiring data for e-maintenance purposes,
- providing remote-services in different network and communication structures.

In contrast to “traditional” engineering, experts in remote engineering are deployed in a relatively broad range of activities that span different sectors of industry. They typically work in locally distributed teams and coordinate their work amongst themselves. This requires not only competent handling of tools and methods for diagnosis, maintenance, monitoring and repair, but above all the ability to communicate effectively with others (e.g. customers, users, installers) with the help of computer-aided means of communication. Skilled service technicians must solve the “mutual knowledge problem”, for example by integrating the know-how of others in order to accomplish their goals using appropriate tools (e.g. electronic conferencing or groupware applications). Special focus must be placed on accessing distributed information from suppliers, customers and manufacturers over the Internet. Because e-maintenance is primarily immaterial, the quality assessment made by customers is highly dependent on those employees who perform such services. For this reason, technicians and engineers must also be trained in customer orientation with an emphasis on communication training and customer-centred action.

With the aforementioned requirements in mind, the general goal in MARVEL is to produce evaluated working examples of remotely accessible practical environments (remote laboratories, workbenches and e-shops) to train engineering students in remote engineering, e-maintenance, remote process control and supervision. Thus, the pedagogical approach is based on the following key aspects: action orientation, teamwork, work process orientation and customer orientation.

Action orientation applies learning and work assignments where students can learn from hands-on experiences with concrete tools and systems. Thus laboratory exercises play a fundamental role in our learning settings.

Teamwork is the core element of e-maintenance. The ability of students to work in teams must therefore be fostered and trained through collaborative learning. The ability to work in teams can only be experienced and practised within learning situations that itself are organised in a team-centred manner.

Work process orientated training focuses on learning scenarios where students can learn in a situated context. Real work tasks as learning assignments and *holistic* problem solving originate from engineering practice and work situations are important.

Customer orientation relates to intercultural competence and the training of non-technical skills like communication training. Learning in distributed environments, collaboration in distributed teams and communication in a foreign language with students from a partner college may help to develop and train these skills.

3 Pedagogical concept

3.1 Experiential learning

The educational concept behind our approach combines experiential and collaborative learning. The theory of experiential learning [4] propagates learning through experience and by experience: learning is a process whereby knowledge is created though the transformation of experiences. One of the main exponents of experiential learning is David A. Kolb [5], who proposes a learning theory comprising four main stages, as illustrated in figure 1: active experimentation, concrete experiences, reflective observation and abstract conceptualization. In his model the process begins with an experience, which is followed by reflection. The reflection is then assimilated into a theory and finally these new (or reformulated) hypotheses are tested in new situations. The model is an iterative cycle within which the learner tests new concepts and modifies them as a result of reflection and conceptualization activities. Two aspects are noteworthy: the use of concrete, “here-and-now” experience to test ideas; and use of feedback to change practices and theories.

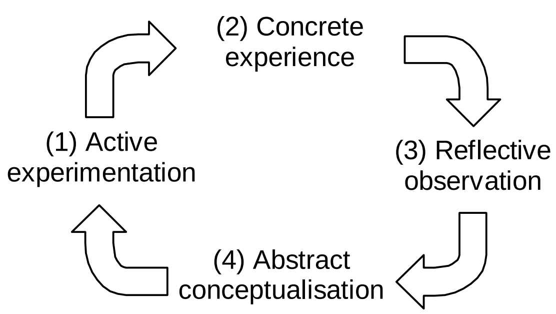

Figure 1: Experiential learning cycle

Lab experiments seem to be very ideal for experiential based training, because lab experiments provide a “hands-on” approach to learning. They allow a learner to 'experience' data in a more familiar form, since the practical experiment proposed to the students enables them to “observe and reflect” on what they have just witnessed. Each experiment may therefore be seen as a starting point on the way that will lead them to understand its underlying theoretical principles.

3.2 Collaborative learning

The collaborative approach associated with our learning scenarios is important for the following reasons:

- Students acquire various soft-skills, such as the ability to work in teams and to achieve objectives in cooperation with others;
- Students learn to communicate with each other using technical expressions that are specific of their professional domain;
- Students learn to integrate the know-how of others in order to accomplish a given work task;
- Students acquire remote collaboration skills, when the teamwork is carried out from several locations simultaneously.

According to the theory of social constructivism, students learn through collaborative interaction with others [6]. The theory of social constructivism addresses two basic aspects of collaboration. The first one involves the relationships among students; students work together as peers, applying their combined knowledge to the solution of a problem. The dialogue that results from this combined effort provides students with the opportunity to test and refine their understanding in an ongoing process.

The second aspect of collaboration involves the role of the teacher; teachers should serve as moderators during the learning process by supporting students how to reflect on their evolving knowledge and providing direction when students are having difficulty. Thus, collaborative learning does not occur in a traditional classroom where students work independently on learning tasks and take responsibility only for self. The focus of traditional groups is generally on individual performance and accountability so that they are not dependent on each other for learning. Independence is actively discouraged. In many cases, working in groups is also much closer to real work situations, when compared with isolated learning. As described above this is particularly evident when concerning the provision of various Internet based services associated with complex systems and networked machinery.

The use of the Internet is not only widespread today, but also very cheap to use and available to almost all the schools and students. This work makes a step towards the introduction of collaborative learning to the regular engineering student by introducing real experiments and highly prised experimental set-ups to everybody with access to the Internet. To this effect the following system is available for use as a learning task both as teamwork and as an independent exercise.

4 The HTI solar energy e-learning lab

The HTI solar energy e-learning laboratory comprises a pilot solar energy conversion plant which consists of two flat plate solar collectors having a surface area of 3 m^2 located on the flat roof of the central HTI building, an insulated thermal storage tank located in the solar energy laboratory and other auxiliary equipment and accessories. It is also equipped with all necessary instrumentation, control and communication devices which are needed for remote access, control, and data collection and processing. The schematic diagram of the system is illustrated in figure 2.

The installed hard- and software includes features for controlling external devices, responding to events, processing data, creating report files, and exchanging information with other applications. All relevant weather data as well as operational and output data of the system are registered during an experimental session and can be stored on the users´ PC for various calculations and/or documentation.

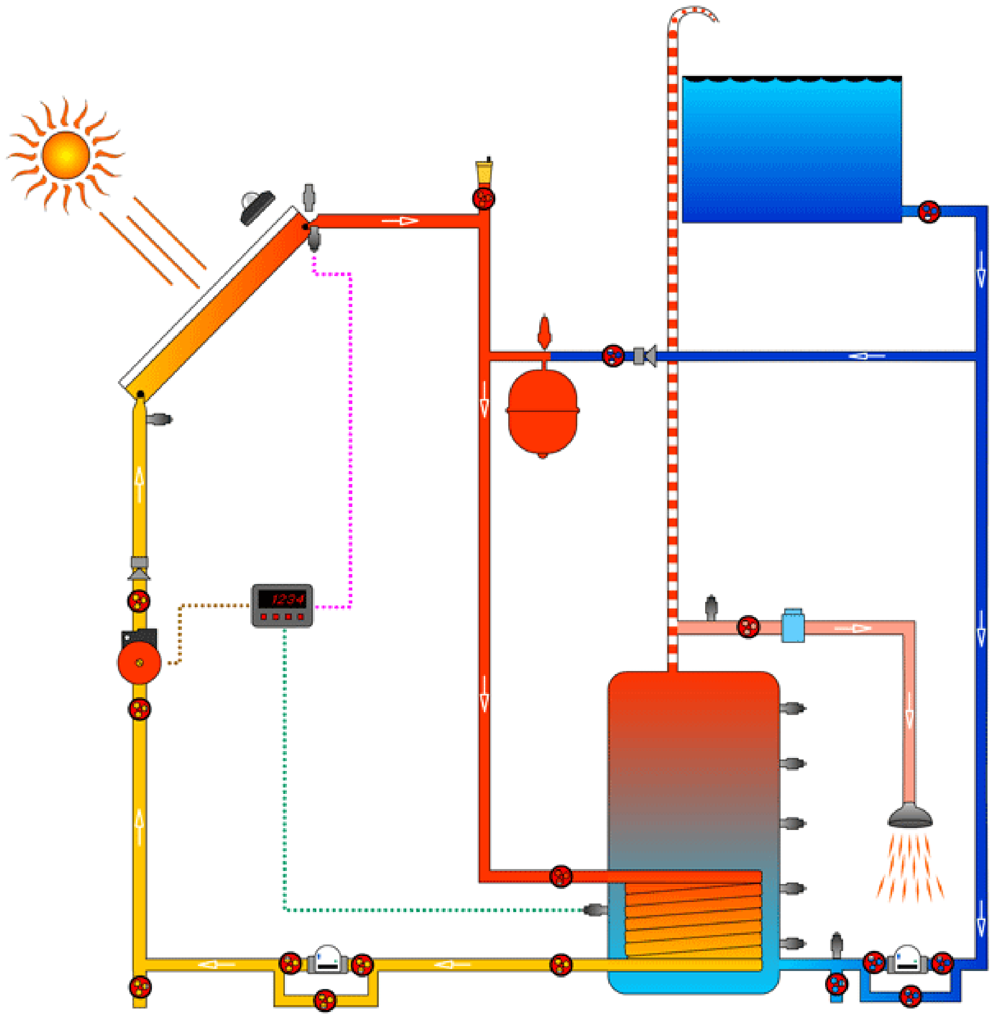

Figure 2: Schematic diagram of MARVEL Solar Pilot System, HTI

A major goal of the HTI solar energy e-learning lab as well as of the MARVEL project in general is the usage of real worlds in virtual learning environments in order to support work-process-oriented and distributed cooperative learning with real-life systems. Telematics, remote and mixed reality techniques are used cooperatively within a network that includes colleges, industry partners, and national bodies dealing with certification and standardisation issues.

The aim is to use the Internet as a tool to make the laboratory facilities accessible to engineering students and technicians located outside the HTI premises, including overseas. In this way, the solar energy e-learning lab and its equipment and experimental facility will be available and be shared by many people, thus reducing costs.

Furthermore, the field of solar energy chosen for this purpose will offer a unique opportunity to students from countries of poor sunshine to have access to real conditions experiments with abundant of solar radiation. The system will enable real-time, remote control, data acquisition and evaluation. It will allow remotely located students to conduct experimental work in an interactive and independent way.

Students from collaborating partner institutions will have remote access to the system. A booking tool would be available to control the access time for the equipment by the instructors. A number of laboratory experiments and learning tasks were already developed including familiarisation exercises as well as system performance investigations and e-maintenance tasks. All exercises and learning tasks are supported by web-based learning materials in the form of 'virtual books'.

5 Learning Platform

5.1 System Architecture

The system architecture used in the HTI solar energy e-learning lab is illustrated in figure 3. The user will be able to have access to the e-learning lab through a PC which will act as web server. This server will host the e-learning platform with all necessary extensions for PHP support as well as the database necessary for this platform. It will also communicate with the machine hosting the TestPoint [7] web server. Whenever a user wishes to get into the system, the communication will be done through this server. That is, the user sends his/her request to the system, the web server communicates with the TestPoint web server and it collects the data and transfers them to the user.

The selected e-learning platform at the web server is Moodle, which is a course management system provided freely as Open Source software (under the GNU Public Licence). Moodle will run on any computer that can run PHP, and can support many types of database, particularly MySQL [8]. This choice allows for flexibility in the learning tools and provides various learning environments to suit the requirements of the various courses [9]. In this particular case Moodle is used as a demonstration, a quiz and an experimental tool. The Moodle capabilities were enhanced so that the running of the actual experimental set-up is only allowed after the successful completion of the preliminary exercises. With this platform, the user can work independently, or work as a team with people from the same class or even from a different school far away talking to each other on the special tool provided at the platform.

The actual running of the set-up is done via the TestPoint, which is an interface tool capable of acquiring data through various sensors, storing the data in a form that the user likes, and processing and handling the data in a meaningful manner. This particular software consists of two parts, the programming and the runtime parts. The programming is needed only to the system designer, while the runtime is necessary to run the particular experiment and is available to the interested user free of charge. Any collected data can be stored in popular programme formats (Word, Excel, etc.) allowing the user to print his own report formats and hand in a report of his choice. This tool is located on a dedicated server allowing faster data handling.

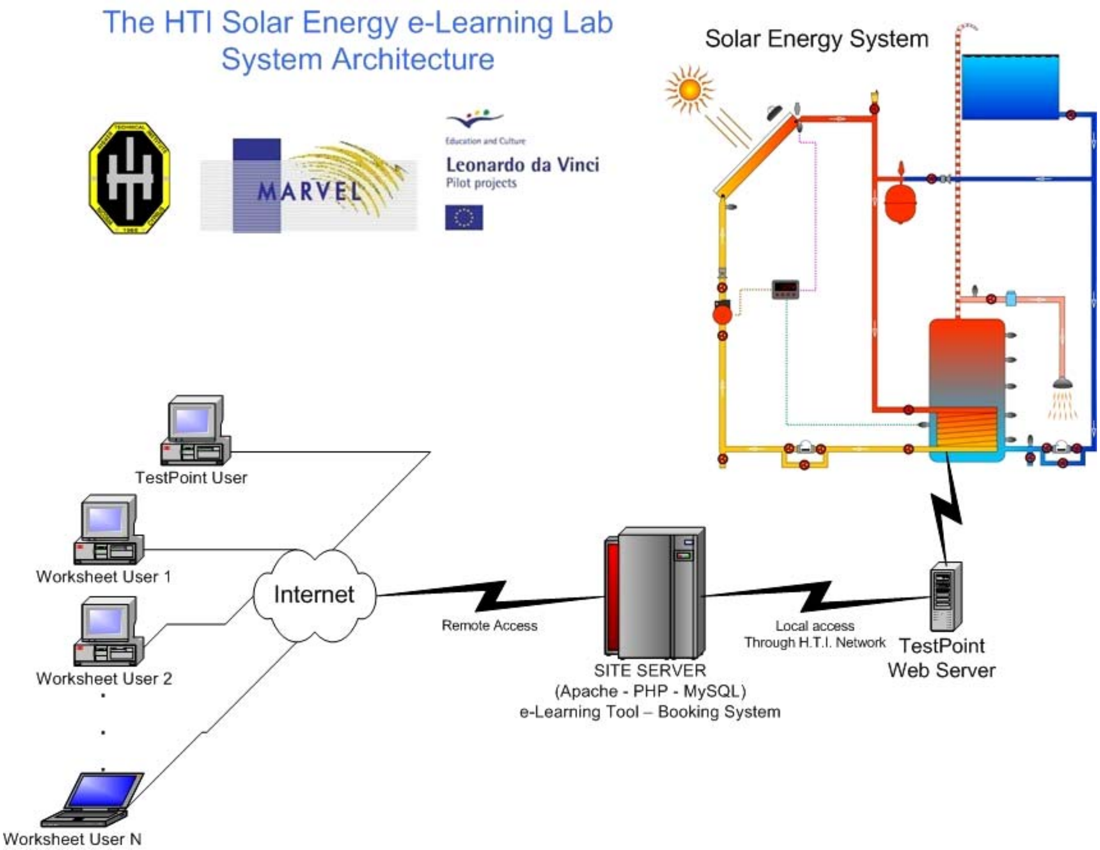

Figure 3: The System Architecture

6 Learning scenarios - Experimental work

The learning scenario comprises a series of exercises of different degree of difficulty and complexity. For each exercise, the student undergoes an online assessment and is allowed to proceed to a real experiment only if he/she is successful to the pre-lab and familiarisation exercises. It also comprises an indexed glossary which includes a good number of terms and definitions related to the solar energy laboratory. Following is a brief description of the four categories of learning exercises:

6.1 Familiarisation with the HTI Pilot Solar Energy Plant

Two introductory exercises were prepared for the prospective user. Their objective is to familiarize the student with the HTI solar energy e-learning lab and make him/her conversant with the components of the pilot solar energy conversion plant. Upon completion of these exercises the student should be able to name each component in the plant and identify the various components needed to construct a solar plant.

6.2 Component functions

Two more advanced exercises for the interested student were also prepared. The objective of these exercises is to familiarize the student with the system layout, make him conversant with the function of each component and the system operation. At the end of these exercises the student should understand the function and operation of each piece of equipment in the system and appreciate its role in the system as well as introduce him into the hydraulics and flow circuits of the plant.

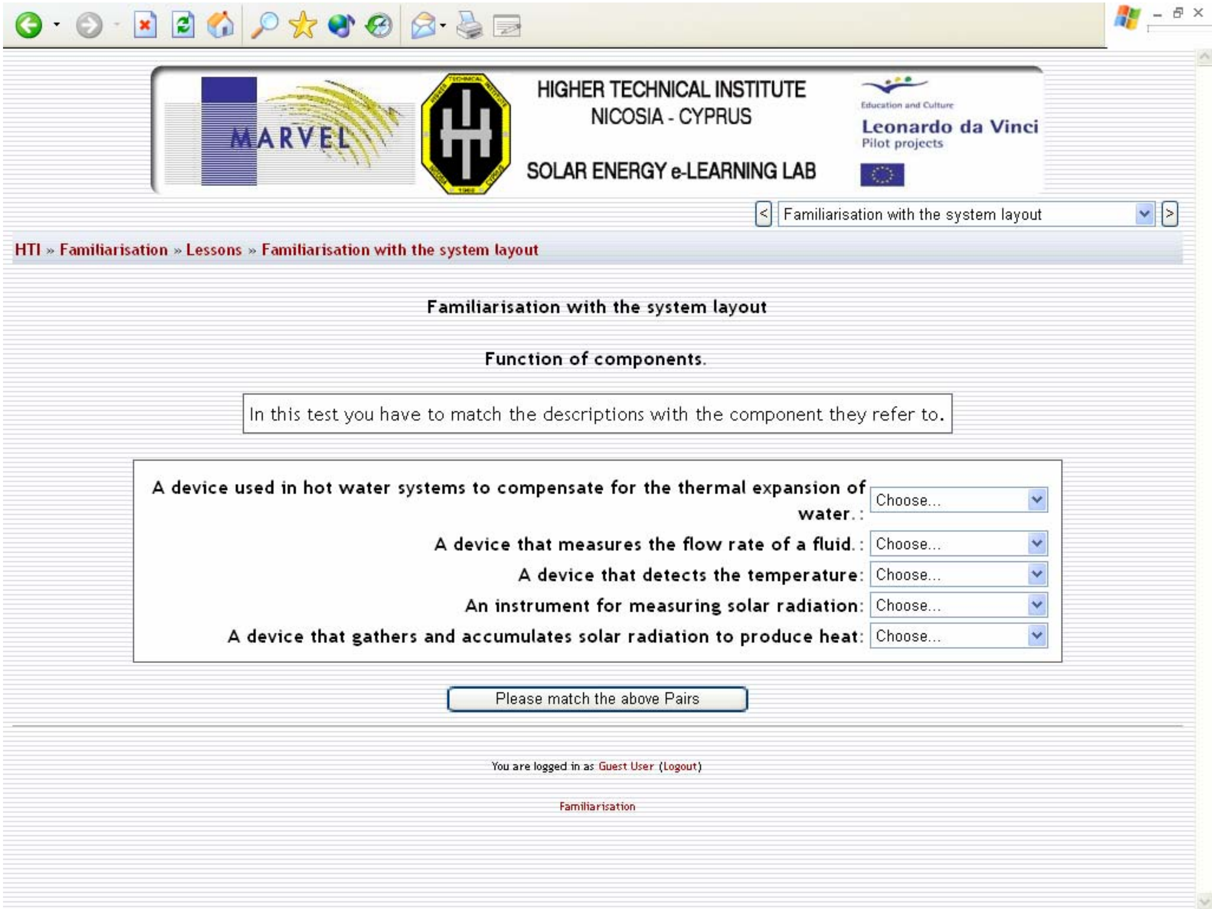

Figure 4: A screenshot within Moodle – Familiarisation with the HTI solar energy plant

6.3 Data collection and Storage tank stratification

This part of the work comprises two more advanced functions of this work. The student will get acquaint with the remote control of the system (getting into the system through the internet, switching ON and OFF the system) and exercise in taking the readings of the various measuring devices, such as temperatures, flow rates and solar radiation. The student will take sets of readings for various conditions and different scenarios. One of the scenarios will be to elaborate on the stratification of temperatures in the vertical type storage tank and get a first-hand experience of the variation of temperatures across the tank at different operational conditions, explain the stratification effect and comment on the results.

6.4 Real Experiment and Investigation of collector instantaneous efficiency

This will take the student into the real world of experimentation with a number of capabilities i.e. to investigate the instantaneous efficiency of the collector or determine the rate of thermal energy removed from the storage tank to the consumption. For this purpose, the student will record a number of readings (incident solar radiation, water flow rates, temperatures, etc.) and using certain thermodynamic equations [10] he/she will determine the performance characteristics of the collector and compare them with those given by the manufacturer.

The student will have the possibility of investigating the above either by the above methodology or directly through the software tool.

The test will be conducted at various conditions and with different scenarios such as for example: with or without consumption of service hot water, at different temperature differentials, etc. Should the student have more time available, he could also plot a graph for the collector efficiency.

7 Conclusion

The HTI e-learning lab goes beyond traditional remote labs: it is providing distributed work places for complex remote learning/ work tasks.

Learning by experience and through experience in a real and social context is restricted in virtual environments. In this paper we present an approach where learning is understood as a process for acquiring information and processing experience in which a learners select and constructs knowledge that is useful and appropriate for him/herself and in turn uses this to drive and determine his/her own continuous learning process. Learning thereby becomes a process of interaction between individuals and his/her work environment, in which the subjective reality of the learner is actively constructed by the learner. These concepts support the social aspects of learning, as learning is necessarily integrated in communication processes between different learning groups while working at the same system or machine.

An important innovation within our approach is that concepts and examples for real working and learning are developed and accessed virtually through remote processes. Accordingly we go beyond 'traditional' remote laboratories, because we are trying to provide distributed work places for remote engineering in technical and vocational training.

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