Creating Hybrid Learning Spaces for Mechatronics Education

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Abstract:

This paper describes some ideas for creating interlinked virtual and real learning spaces with a special focus on mechatronics education. Experience gained in the European project MARVEL, in which on-site and remote laboratories, theory and practice merge into a cooperative learning process, are discussed and further perspectives elucidated. The concept of combining, linking, and merging real work systems with virtual learning environments to create a hybrid learning space marks a change of perspective in technical education and training. Integrating virtual learning platforms in real-life work situations, and vice versa, complements traditional setups involving eLearning, on the one hand, and learning at the work place, on the other.

1 Introduction

In modern technical education and training, an important role is played by learning concepts which closely link learning and work, and which develop key skills that equip employees to cope with open work assignments and the rapid pace of change. The need for work-related learning based on the interleaving of theoretical learning and learning in practical tasks, experimentation and field work is obvious [1]. Accordingly, there is a growing need for innovative concepts, capable of supporting the necessary education and training platforms. eLearning systems and virtual learning sessions (online labs, simulations) extending to real labs or to the work-place can contribute significantly to a successful outcome of this learning process. The MARVEL pilot project (Virtual Laboratory in Mechatronics: Access to Remote and Virtual eLearning) was designed to foster learning concepts that serve these actual needs in the subject area of mechatronics [10].

2 Limitations of virtual learning environments in engineering education

Although recent years have seen major efforts being invested in virtual learning environments as tools of supporting and fostering learning geared to real work processes and activities, current studies in this field have revealed some general shortcomings, and above all, a lack of options for integrating digital learning systems in real-life work situations [14]. One of the main causes for this is that most virtual learning platforms are relatively closed systems and cannot be synchronised with operating data in a way that advances learning – for example by importing real-time operating data, simulating current real-world projects, and integrating existing descriptions of processes and products. The result is a lack of authenticity in learning assignments and hence a relatively disconnected mix of eLearning-based theory courses, on the one hand, and on-the-job learning, on the other. It is obvious that under such conditions the transfer of what is learned from the learning context to the actual field of application or practice, and vice versa, will not succeed, or receives will receive too little support from virtual learning platform and eLearning tools. There appears to be a lack of didactic and corresponding engineering concepts for networking real work systems and processes with 'virtual learning worlds', in a way that fosters learning by enabling transitions between virtual and real worlds. Implementing virtual learning environments on the basis of classical educational concepts is obviously inadequate as an approach. Combining new and old learning media in the form of 'blended learning', but leaving their conventional teaching methods untouched is also not enough.

3 Integrating real and virtual learning venues

Learning with digital media or tools, and learning in the midst of the real physical world seem to represent opposing learning cultures. Thus research efforts in connection with the MARVEL project were geared towards integrating real and virtual learning venues in order to forge stronger links between theory and practice (figure 1). Efforts are focused on the enrichment of real-life work environments with virtual learning worlds, on the one hand, and using real plant and machinery in virtual learning systems, on the other hand. Learning scenarios and environments were developed and tested that allow access from different learning venues,to real production plant and engineering laboratories. The intention was to facilitate collaboration between different learning venues (e.g. technical colleges, training enterprises, universities), and to put the actors involved (apprentices, students, instructors) in a position where they can jointly use real production plant and laboratory facilities over the Internet and deliver collaborative courses and lectures within a learning community.

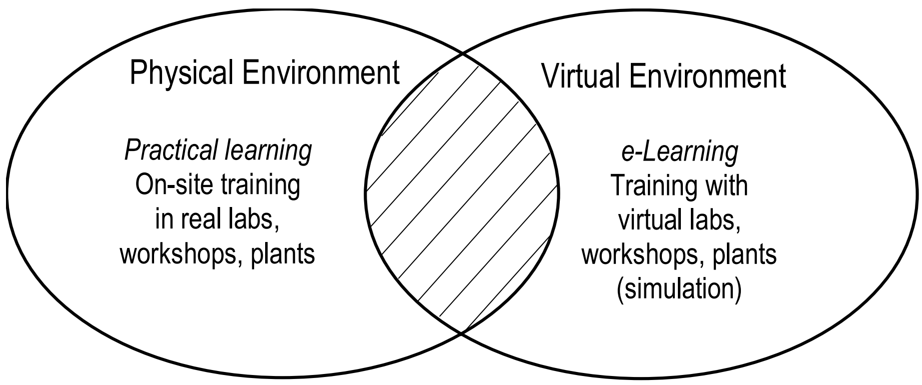

Fig. 1: Integrating real and virtual learning environments

One main objective in MARVEL was to develop and test interlinked physical and digital environments for engineering education and training, in which complex and realistic tasks can be performed by learners in collaboration. We refer to these environments as *hybrid learning spaces*. Our aim here was to demonstrate that such learning spaces can be created with relatively simple means by using existing Internet applications for remote observation, control and maintenance [2], and by networking them via an eLearning portal. Such a network of distributed facilities (labs, workshops, plants) were implemented in MARVEL and tested in various course trials (figure 2).

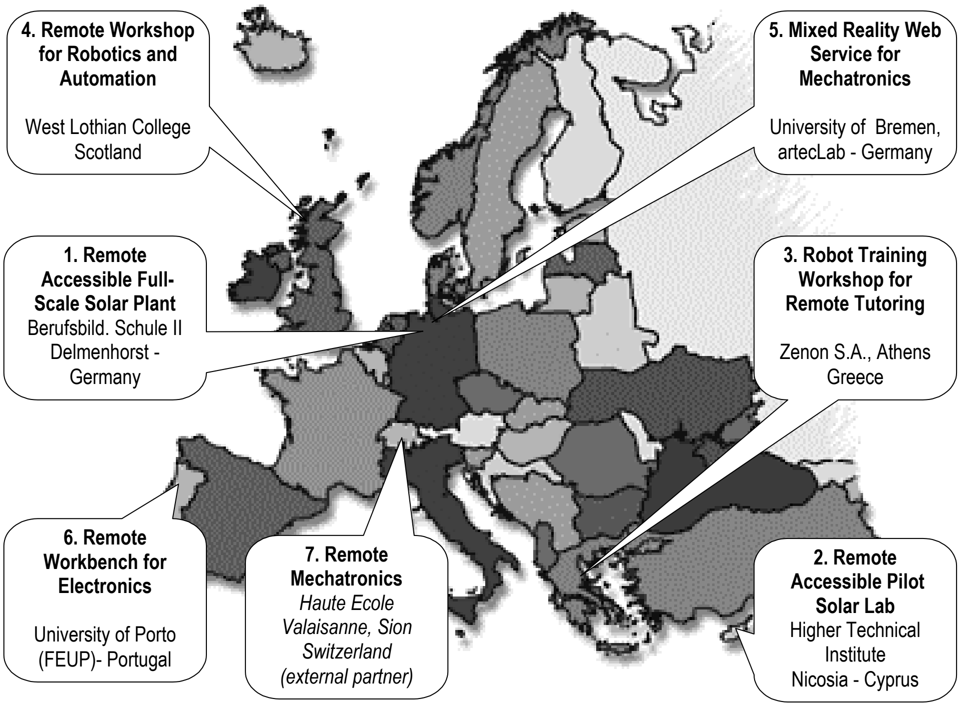

Fig. 2: The MARVEL network of distributed labs and workshop facilities

In order to develop a feasible approach to the design of hybrid learning spaces, compromises have to be made between the aim of maximum coverage of the specific field of training, and the desire for an easily handled system that necessarily reduces this complexity, and helps to improve the scope for decision-making and activity within the educational setup. In MARVEL, we developed a model for the design that is described in the next section.

4 A model for creating hybrid learning spaces

Our concept concentrates on three selected aspects, and provides an model from an educational, psychological and organisational perspective. To illustrate the multi-dimensional dependencies involved, we propose a spatial taxonomy (see figure 3). A distinction is made between the following dimensions:

(1) learning media and tools, and the specific form in which they are represented (physical and real, or digital and virtual),

(2) learning venues (e.g. school, university, factory, learning at home) and the associated types of learning (e.g. face-to-face or remote learning, distributed learning) and

(3) learning activities (analytical or constructive) and the associated learning styles (e.g. abstract, concrete, active, or reflective).

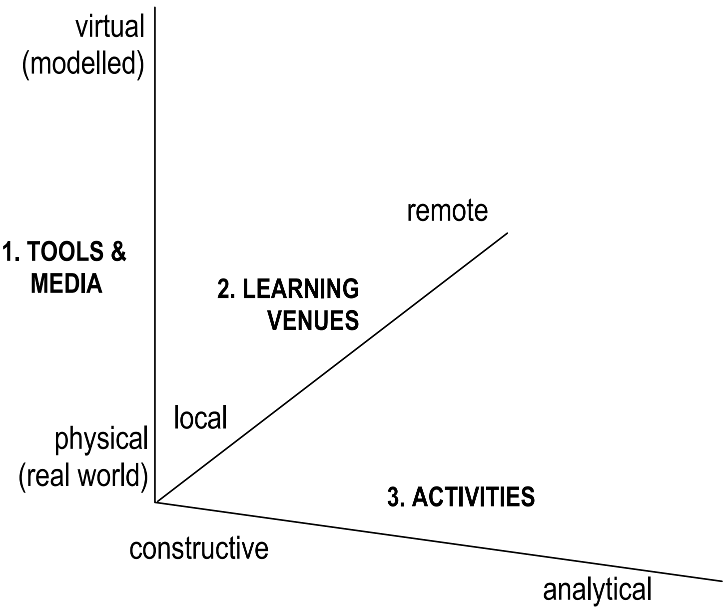

Fig. 3: Dimensions of Hybrid Learning Spaces

4.1 Learning media and tools

The first dimension in this taxonomy covers the continuum between physical reality and digital virtuality in respect to different learning media and tools. These range from physical, real-world objects and media to purely virtual objects and media. An example of the former is learning with real tools and machines in an actual work process. At the other end of the scale we have learning with digital media, in virtual laboratories or with computer simulations [5]. Between these two extremes there are various mixed forms, such as learning with and on physical systems and processes of reduced complexity, but close to reality nevertheless. Learning in physical reality involves direct contact with tangible objects, real events and other people. Virtual learning involves symbolic activities that are not based on direct experience, but are communciated instead through digital and graphic media. This is the method normally found in classroom learning.

As can easily be seen, the dimension of learning media and their specific form of representation imply very different types of experience with real and virtual objects. Let us look, by way of example, at learning with computer-based simulators, i.e. at experimentation using virtual, digital models. Examples of such systems for training and skilling purposes are training simulators for working with specific equipment, machines, technical plants, or other devices and apparatuses. In most cases, the aim is to learn how to operate the system under different conditions, and to train particular responses to malfunctions or emergencies. Examples here are simulators for turning and milling, or for assembly robots. The most important didactic aspects of such training systems are the reduced risk associated with operator error, and the opportunity to experiment and practise without being exposed to hazards.

On the other hand, direct, sensomotoric experience with physical objects are a basic requirement for ‘grasping’ the material involved. Piaget drew attention to this phenomenon long ago, when he described how cognitive development is generally rooted in the child’s manual, tactile interaction with the objects in its environment [13]. In the same way as manipulated objects respond with a specific reaction (due to hardness, elasticity, roughness, heat, cold, etc.), the manner in which individuals deal with them is rooted in action schemes, mental images or cognitive models. Technical education and training must take this aspect into consideration and devise appropriate learning situations in which handling specific tools, machines and facilities in a holistic and haptic manner is not only a key prerequisite for learning psychomotoric skills. Is is also an excellent opportunity for creativity – in developing innovative ideas, or communicating something to another in a relatively simple and uncomplicated way, and demonstrating this on real objects. To that extent, sensory interaction with objects also has a key supportive function that can be very helpful in learning about complex interrelationships. It should be obvious that virtual systems and computer simulators are unable to achieve this, and that physical objects must be used in their place. For this reason, it makes didactic sense to combine virtual/digital and real/physical learning objects, as described in the following learning scenario from the MARVEL project: "Vocational trainees perform an assignment in the field of control engineering. A computer-based model is generated in order to simulate malfunctions in virtual reality. An identical real-world system is then constructed using components typically used in industry. The main focus in working on this assignment subsequently consists in different groups of learners jointly devising a solution that is subsequently implemented on the real system."

4.2 Learning venues

A second dimension derives from the fact that learning may occur at different venues (school, university, factory, home, etc.), and with corresponding time structures. Distinctions can therefore be drawn between many different forms of learning, such as classroom based learning, telelearning, distributed learning, and self-organised learning, etc. Every type of learning has advantages and disadvantages. A key challenge in supporting learning based on work processes is to create networks linking different learning venues. Networks that integrate work environments, workplaces and work processes in new learning venues can be exceptionally complex. The constituent elements of such networks include, for example, lessons in collaboration venues, collaborative further training of teaching staff, development and delivery of learning resources independently of learning venue, and support for the exchange of information and knowledge between different learning venues. There is a need for coordination on the issue of how different learning venues can be networked technically and organisationally so that theoretical and practical components are intermeshed, and the mobility and flexibility of participants enhanced.

Mixed Reality environments[1] may help supports learning networks that link theory and practice, because it allows flexible couplings between distributed virtual and real systems. These links can be unidirectional or bidirectional, so it is possible, for example, to use real learning media remotely, and combine these with virtual representation at the local venue. This is illustrated by another learning scenario from the MARVEL project: "A group of learners reconfigures and programs an automation system. Use is made of available materials and simulation software. In a further step, the result is then tested on a real system at a remote location (e.g. an enterprise). Access to the real system is obtained by transmitting control programs and parameters into the system via the Internet and a virtual reality interface. A second group of learners monitors the process on site and provides feedback via the respective communication systems."

[1] Mixed reality – a concept in which virtual information generated by computers is mixed with the real environment [8, 12].

What is interesting here from the didactic perspective is the networking of different workshop facilities or real laboratories that are located in different educational institutions or enterprises. The quality of training can be improved as a result, because distributed and scarce resources can be shared in a network of learning venues. Supporting tele-collaboration between different technical education institutions at regional and supraregional level raises certain research issues regarding synchronous and asynchronous learning, but these will not be pursued any further at this point.

4.3 Learning activities

Finally, the third dimension of the model derives from the fact that learning processes are based on a broad diversity of activities. These can basically be constructive or analytical in structure. Constructive activities are practical in nature, whereas analytical activities consist of observing, interpreting, reflecting, etc. The latter do not interfere with reality, but only subject reality to analysis. To that extent, they are risk-free and non-committing. In the case of constructive activities, in contrast, which interfere with reality and produce or indeed destroy new objects and facts, the person engaged in such activity bears responsibility for its effects. The level of earnestness is greater here than is the case with analytical activities. Its relevance for vocational training is clearly apparent. A mixture of constructive and analytical learning activities is certainly expedient in most learning situations. Different learning styles that can vary according to situation, problem or previous experience play a central role in this regard. In addition to visual, auditory, kinaesthetic, and haptic learning types, a distinction is also made in the literature between abstract, concrete, active, and reflective learning [6].

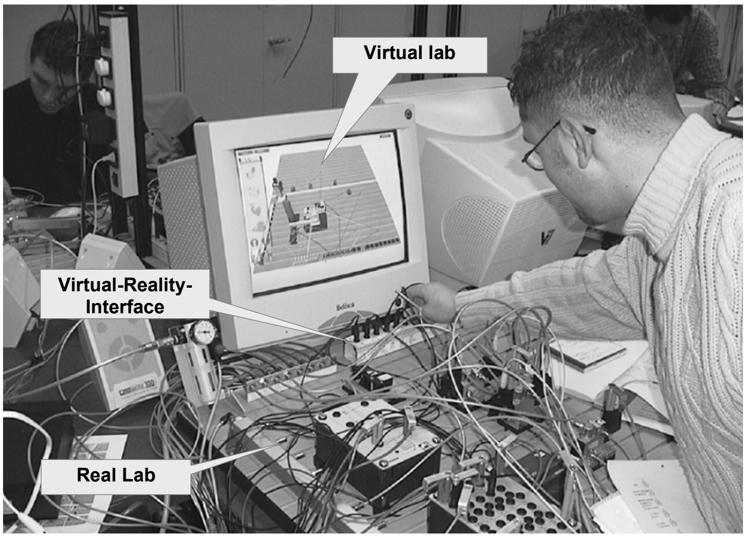

Fig. 4: Mixed Reality Web Service for mechatronics (deriveSERVER)

In MARVEL we used Mixed Reality technologies for learning environments to resolve the strict separation of real and virtual, and permit a focus on how they can be linked and imaged as networks of real and symbolic systems. The concept facilitates bridges between practical, direct experience from constructive activities, and symbolically communicated experience from analytic activities. Viewed in this way, Mixed Reality is a link for connecting aesthetic experience and abstract modelling in the educational context. A novel learning lab for mechatronics training - called deriveSERVER is based on those ideas. In addition to purely remote or local labs, where all devices are real, the deriveSERVER is a distributed and collaborative eLearning platform that integrates real and virtual, local and remote media for electropneumatics under a common interface (figure 4). The system is based on Hyperbond technology [3], which provides the means to combine real and virtual worlds freely.

With the deriveSERVER, local and remote learners can work together on different levels of abstraction ranging from real components, to three-dimensional virtual worlds and symbolic representation. A key feature of the system is the function of freely replacing virtual parts by real ones and vice versa. This makes it possible to build hybrid electropneumatic circuits combining real and virtual components. By dragging and dropping objects from a library onto the working area, new elements are added to the system and interconnected to build the experiment. If the status of the real system changes, the virtual simulation model reacts accordingly – modifications in the real world result in an update of the virtual system. This generates new perspectives for linking constructive and analytical learning, in that virtual and real components can be compiled to form complex machinery. Constructive activities are aimed at building real components, analytic activities at cognitive understanding of virtual components.

5 MARVEL learning scenarios

The concept of combining, linking, and merging real work systems with virtual learning environments to create a hybrid learning space where implemented and tested in different learning scenarios assessed in MARVEL. Case studies addressed various mechatronics projects, but concentrated initially on process control, industrial robotics, electropneumatics and electronics. An overview of these learning scenarios is presented in the table below (Table 1). For further details, visit the MARVEL website at http://www.marvel.uni-bremen.de.

	Learning scenarios	**Partner involved**	**Settings and course trials**
1	Distributed process monitoring, control and maintenance of full scale solar plants	Berufsbild. Schule II Delmenhorst Higher Technical Institute (HTI) Germany - Cyprus	Classroom-only and various types of hybrid classroom-work place learning settings, including remote experiments and teaching sessions with teams from partner colleges in different countries.
2	Distributed process monitoring, control and maintenance of pilot solar plants	Higher Technical Institute (HTI) Berufsbild. Schule II Delmenhorst Cyprus - Germany	
3	Configuration and programming of an industrial robot with tele-tutor support	Zenon S.A., West Locian College (WLC) Greece - Scotland	
4	Distributed diagnosis and maintenance of a modular production system	University of Bremen, artecLab University of Porto, FEUP Germany - Portugal	
5	Exercises in remote engineering and mechatronics	West Lothian College (WLC) Zenon S.A., Scotland - Greece	
6	Remote experiments in electronic circuit design	University of Porto, FEUP University of Bremen, artecLab Portugal - Germany	

Table 1: MARVEL learning scenarios

Within the MARVEL learning scenarios, we combined simulation training, remote lab experimentation and learning-by-doing on real-life systems to reduce problems in knowledge transfer between virtual and real systems. Examples of real working and learning were developed and accessed virtually using remote processes. These solutions foster the social aspects of learning, as learning is necessarily integrated in collaboration between different learning groups while working on the same tasks. One important aspect is that the media and tools used in MARVEL are at the same time a part of the working/learning process itself.

In the first step, course trials were tested in local settings with students [11]. Distributed learning scenarios were then evaluated, in which students accessed virtual and physical laboratories and workbenches from a remote partner institution. A teacher, assuming the role of a teletutor, supported these learning sessions via the Internet. In further course trials, distributed learning groups collaborated via the Internet and solved a typical maintenance task, requiring them to program and/or configure a real mechatronics system. For safety reasons, their ability to modify parameters remotely was limited, and the learning task were supervised by an instructor at each site. As a complementary action to distributed settings, teachers held a joint teaching session with partner colleges, using their local lab facilities. Generally, most learning settings addressed the following qualifications and skills:

- Theoretical knowledge and operational competence to monitor complex processes from distributed locations (using IT tools for process monitoring and control).
- Theoretical knowledge and operational competence to determine the efficiency of different system configurations (using IT tools for data acquisition).
- Competence to maintain complex systems (e.g. finding faults) with IT tools and adequate methods.
- Ability to collaborate with technicians speaking a different language, and having different cultural and professional backgrounds (e.g. in a company with several branch offices all over Europe).

We used the MOODLE software package for course management and delivery, and as a gateway to give access to the remote resources and tools [4].

6 Conclusions

Our model of hybrid learning spaces is an orientational guide for designing, providing and evaluating interlinked virtual and real learning environments. We pursue a three-fold objective with this concept. Firstly, we want to provide an instrument with which the didactic range of virtual and real learning media and tools can be better evaluated. The second aim is to evaluate the role of the learning venue (face-to-face learning, remote learning, distributed learning, etc.) in a more differentiated manner with regard to the other dimensions. Thirdly, we aim to provide an framework with which different learning activities (both constructive and analytical) can be analysed in relation to different learning venues, media, and tools. It is essential that this approach is not seen as a purely procedural model, but rather as a heuristic system for research and development centred on work and learners. Consideration must be given to the fact that every human has his or her own individual way of learning, and prefers different strategies and approaches. It is important to take different learning styles into account, and that learning situations leave plenty of room for different ways of acquiring knowledge and skills. Having recourse to a variety of different forms of learning is particularly necessary in the case of eLearning.

The MARVEL project pursues an innovative paradigm in engineering education and vocational training, by supporting local and distributed learning based on merging virtual and real labs and workshop facilities. This allows combinations between workplace-oriented and co-operative learning in a training network of different stakeholders. Our approach is a step to achieving "Virtual-Reality eLearning" in a particular field. eLearning or even Blended Learning – characterized in the classical sense as web-based training combined with classroom teaching – is limited in scope, because learning experiences are mostly restricted to virtual situations. That is why a learning concept based on hybrid learning spaces could promise new pedagogical perspectives.

7 Acknowledgements

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