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Digital Learning Environments for Joint Master in Science Programmes in Building and Construction in Europe: Experimenting with Tools and Technologies

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***Abstract*—**Recent developments in information and communication technologies (ICT) have created excellent conditions for profoundly enhancing the traditional learning and teaching practices. New modes of teaching in higher education subjects can profoundly enhance ones ability to proactively constructing his or her personal learning universe. These developments have contributed to digital learning environments becoming widely available and accessible. In addition, there is a trend towards enlargement and specialization in higher education in Europe. With as a result that existing Master of Science (MSc) programmes are merged or new programmes have been established that are offered as joint MSc programmes to students. In these joint MSc programmes, the need for (common) digital learning environments capable of surmounting the barriers of time and location has become evident. This paper discusses the past and ongoing efforts to establish such common digital learning environments in two joint MSc programmes in Europe and discusses the way technology-based learning environments affect the traditional way of learning.

***Keywords*—** education, engineering, learning environments, ICT.

I. Introduction

The current state of the European Building and Construction (BC) industry can be characterized as very fragmented and traditional. Until recently there were no incentives to change. However, the increased pressure from society and government persuaded the BC industry to change towards a more innovative and competitive branch of industry [1]. A number of reform programmes have been initiated by national governments to facilitate this change such as the Rethinking programme in the United Kingdom and the PSIBouw programme in the Netherlands.

Now that the European BC industry has taken up a position towards addressing the consequences of the increased pressure from society and government, it places heavy demands on the competence of the industry - a new type of competence that is not the same as it used to be. Therefore the BC industry must change. These types of changes require a change in "decision, doing and acting" within the BC industry, i.e., it implies a continuous change in the needs of skills, competences and knowledge of employees working in today's BC industry [2].

Following higher education for a couple of years and afterwards have a job for life is a picture that belongs to the past. In order to provide an answer to the continuous changes of skills, competences and knowledge, the BC industry has adopted the concepts of Continuous Learning and Life-long Learning. From the perspective of higher education institutes this implies an increasing demand for specific (post-) graduate education programmes. It also poses demands on the availability of digital learning environments that suit to the specific needs of supporting the concepts of Continuous Learning and Life-long Learning.

II. Trends in Higher Education in Europe

The increasing demand for specific (post-) graduate education programmes has led to the development of a number of specific "joint" Master of Science (MSc) programmes in BC in Europe. These joint MSc programmes are established in cases when a single higher education institutes cannot cover a specific field of BC. In such cases, collaboration between higher education institutes in Europe is a way to complement the dispersed knowledge [3].

A good example of such collaboration between European higher education institutes is the European joint MSc programme in Construction Information Technology, referred to as the ITC Euromaster. The ITC Euromaster has been the result of collaboration between University of Algarve (Portugal), Delft University of Technology (Netherlands), Dresden University of Technology (Germany), Glasgow Caledonian University (United Kingdom), Lisbon University (Portugal), University of Ljubljana (Slovenia), Lulea University of Technology (Sweden), University of Maribor (Slovenia), and University of Salford (United Kingdom) and has been developed within (and funded by) the European Erasmus programme between 2001 and 2006. During this period, the involved higher education institutes developed together a curriculum on Construction Information Technology

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which complements the existing portfolio of educational programmes at each of the involved institutes [4,5,6]. Although the ITC Euromaster has been developed as a complete MSc programme, most involved institutes decided not to run the whole programme but to incorporate some of the modules of the programme into the existing curricula and offer specific modules through Lifelong Learning/Continuous Learning programmes.

Another good example of a joint MSc programme in Europe is the Dutch inter-university MSc programme in Construction Management and Engineering (CME). The motivation for the MSc CME programme has originated from the Sector Plan "Power in Innovation" in which the three universities of technology (3TU) in the Netherlands - Delft University of Technology (TUDelft), Eindhoven University of Technology (TU/e) and the University of Twente (UT) – indicate how they aim to create a single federation of the Dutch universities of technology by combining their educational and research programmes and enhancing their activities in the field of knowledge valorization by 2010. With this comprehensive co-operation and co-ordination, the three universities of technology combined their forces in order to raise the Dutch "knowledge" economy from its mediocre position in innovation [7,8]. In the Sector Plan, the MSc CME programme was one of the five MSc programmes considered to be essential for the Dutch knowledge economy. Although competitive MSc CME programmes already were offered at the three universities, the former competitors were able to overcome their mutual suspicion and have developed together a joint two-year MSc CME programme which has been accredited in 2006. Currently, the MSc CME programme is offered as an MSc graduation programme to the regular students at the three universities and offered in an adjusted form as MSc and MBA postgraduate programmes to construction professionals as part of their Lifelong Learning/Continuous Learning programmes.

In order to overcome the particularities of joint MSc programmes and Lifelong Learning/Continuous Learning the need for (common) digital learning environments capable of surmounting the barriers of time and location have become evident. In the next paragraph, digital learning and digital learning environments will be discussed.

III. Digital learning and Digital Learning Environments

Recent developments in information and communication technologies (ICT) have created excellent conditions for profoundly enhancing the traditional teaching and learning practices. For example, lecturing is a long standing tradition for transferring knowledge from teacher to students. For some time the efficiency of this method has been questioned [9]. For instance, a closer look at the Learning Pyramid of Bales (Table 1) indicates the average retention of knowledge with respect to several methods of transferring knowledge and learning modes [10].

TABLE I
LEARNING PYRAMID OF BALES.

Method of education	Average retention (%)
Traditional lectures	5
Reading	10
Audio-visual	20
Demonstration	30
Discussion group	50
Exercise	75
Self-teaching	85

Bales has revealed that the traditional lecture as mode of teaching provides the least retention of knowledge. This is a rather passive way of learning and in particular with decreasing usefulness with the increasing of number of attending students where the opportunity for dialogue makes place for monologues. This has always been compensated by stimulating students to learn by reading (learning by self study), audio/visual/live demonstrations (learning by senses), discussions (learning by dialogue) and exercises (learning by doing). The latter has always been the essence of teaching BC disciplines [11].

The full potential of digital learning can only be exploited by creating effective digital learning environments that are capable of facilitating all methods of education. Nevertheless the most important and crucial element remains to be the commitment and motivation of students. This is an essential factor in increasing effective digital learning. This also means that the digital learning environment needs to be flexible and inviting. It also needs to take into account conditions and possibilities of individual students. These digital learning environments can introduce a greater degree of self learning. Digital learning from this perspective must be viewed as associated with and not separated from practices of producing, spreading knowledge about, as well as using ICT and digital media concretely in everyday learning and teaching practices. Digital learning environments will be used as an enabler for creating the personal freedom for a student who will be able to learn at the most convenient time and using the most appropriate personal mode of learning. The role of the teacher is in fact influencing the exploitation of this freedom by offering different modes of knowledge transfer and learning modes. In other words this is a well thought of process that is offered to students counting on their motivation and commitment [12,13,14].

In a digital learning environment the learning process may be either a solitary individual activity or a collaborative group activity where both synchronous and asynchronous communication can take place or a combination of these. However, learning in isolation in order to memorize for the examination should become obsolete because they only reinforce short-term knowledge. Knowledge acquisition and application of the knowledge need to take place and repeated at the same time and in different variations. Understanding theories, methods and techniques of active learning provides an important context for defining learning strategies and the potential importance of practices such as working in small

groups, learning by doing, working with real-life problems and interactive exchanges [15,16]. The learning strategy should be designed for developing insight and understanding of the theoretical framework of subjects and constructing meaningful didactics for a digital learning environment. In this regard the starting point is the business processes, i.e. the education process starting from subscription till becoming an alumnus. The information processes will be defined in terms of which functions are needed and considering the use of open specifications and standards (i.e. providing interoperability).

With respect to the interoperability issues, it is important to broaden the discussion to look at the architecture of a digital learning environment as a digital working environment and not solely as the classic virtual learning environment such as Blackboard, WebCT and TeleTOP. The information process that is required to support a student's learning process should not be hindered by technical barriers. Even if the underlying systems are different, the front-end interface for the end-user may still be one coherent environment. Furthermore the technical processes will be defined in terms of which tools are required, the client/server architecture, an integrated system or a combination of interoperable technical components, et cetera [17]. In the next two paragraphs, these technical issues will be discussed in the context of their application within respectively the ITC Euromaster and MSc CME programme.

IV. The ITC Euromaster Case

One of the immediate positive effects of the project is a continuous cooperation between the involved universities. In this regard many digital learning strategies or ideas were developed, compatible with the goals of the project, including an early distant learning experiment between the University of Dresden and the University of Maribor by using videoconferencing and application sharing technology in 2002. The main goal of the experiment was to improve the teaching and learning methods with a special focus on web-based distant learning technologies. In the final module guest-lecturers from Carnegie Mellon University were invited to present their experiences and research results and thus enhance the scope of the experiment to a global level. The learning materials were presented to the class by sharing a common presentation application. The learning materials were additionally made available to the students through the existing web-based platforms of each involved university. Using separate platforms allowed for individual time schedules and additional seminars taught individually. Figure 1 shows the main course infrastructure used during the experiment [18].

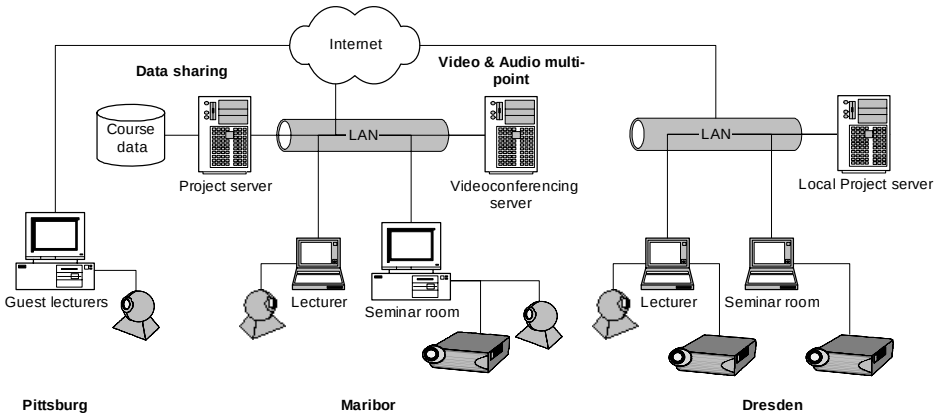

Fig. 1 Main course infrastructure.

Different software (CUSeeme videoconferencing server and clients, VCON MXM server, vPoint client and NetMeeting) and different types of supporting infrastructure were used during the experiment. At the University of Maribor for example, a completely equipped digital learning lab, including two video cameras and a sophisticated audio system with wireless microphones was available. Additionally the lab is covered with LAN and W-LAN access points, which allows students to access the broadcasted teaching material with their own laptop computers in a variety of ways [19]. Figure 2 and 3 show two screenshots made during the experiment.

Fig. 2 Videoconferencing (vPoint client)

The main findings from this experiment are:

- Active participation of students requires a backbone with sufficient performance for bi-directional audio and video transmission;
- A video connection is essential for interactive student-teacher communication. According to individual interviews, students requested for video communication for avoiding "anonymity" of the teacher;
- Application sharing, including the share of control would

help to develop future distant learning scenarios. But interactive cooperation is more than using some software or documents together;

- Personal contact with teachers or teaching assistants will still be necessary for individual guidance and support.

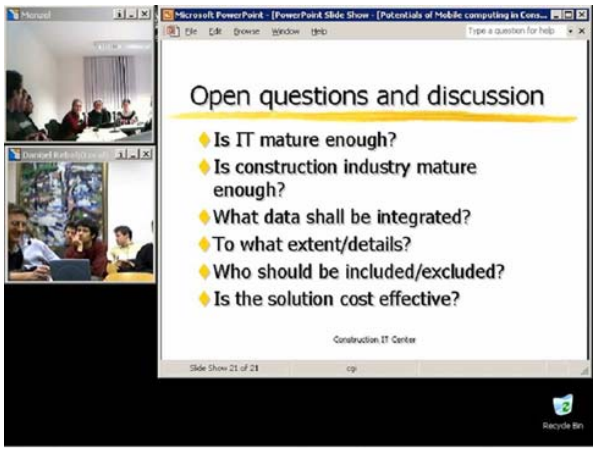

Fig. 3 Application sharing (NetMeeting)

During the period 2003-2004, the involved universities started to experiment with ClickToMeet (CTM) technology. CTM is a technology brought on market by RADVISION. CTM is a Client/Server solution for online meetings which runs on standard server hardware and platforms and enables client personal computers with rich media communication tools (e.g. audio & video, chat, web touring, document presentation, whiteboard and application sharing). Although the experiment faced a number of technological problems (e.g. stability, firewalls, video lag, hardware compatibility etc.), the conclusion was that CTM is a good candidate to serve as a basis for a virtual classroom for the ITC Euromaster. After solving most of the technological problems and with the introduction of version 4.1 the involved universities decided to implement CTM within the digital learning environment for the ITC Euromaster. Figure 4 shows a snapshot from the CTM Client (an auto-installing browser-based tool).

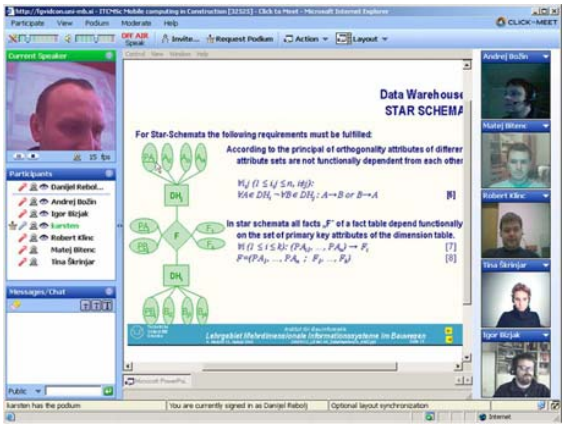

Fig. 4 ClickToMeet (CTM) client

Another main part of the digital learning environment for the ITC Euromaster is a learning portal. The main function of this learning portal is to enable access to learning materials from any location on the Internet. Additionally it can help the involved universities to organize courses, it can support teachers in preparing, structuring, and storing teaching materials, but also to organize and run classes, and it can enable students to communicate with their teachers and colleagues, and to collaborate on common projects. The learning portal is based on the Modular Object-Oriented Dynamic Learning Environment (MOODLE, Figure 5). Both learning portal and virtual classroom are interlinked and function as a single integrated system.

The experiences in the current ITC Euromaster programme showed that much effort is necessary to prepare high-quality digital learning materials, to become familiar with the on-line teaching, learning and communication and to manage and further develop the digital learning environment. The established digital learning environment is very stable and well running. Except of some audio fine-tuning and (local) bandwidth problems at the beginning of the academic year, the lectures run perfectly throughout the semesters [20,21].

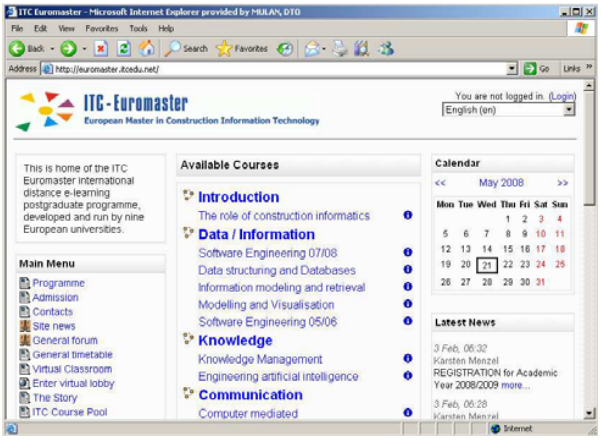

Fig. 5 ITC Euromaster learning portal

V. The MSc CME Programme Case

While most 3TU MSc development groups primarily focused on the development and organization of their curriculum, another group ICT & Education and ELO-Groupware (ICT&E) tried to sketch a realistic perspective for a future digital learning environment for the 3TU graduate school (GS). Because the 3TU MSc development groups were primarily focused on their curriculum, the ambitions with regard to ICT-based teaching and learning were rather modest. Therefore, one of the problems of the ICT&E group was that it was not very clear what was needed and when it was needed to facilitate the 3TU MSc curricula. The danger of this situation is that the discussion narrows down to all kinds of interesting and nice working tools which from ICT perspective cannot be managed [22].

Another problem of the IT&E group was the fact that the three locations of the 3TU GS already implemented different

and rather traditional and closed (in terms of interoperability) digital learning environments based on technology provided by Blackboard (TUDelft), WebCT (TU/e) and TeleTOP (UT) that are integrated with the internal ICT infrastructures and information systems at the three locations. The IT&E group denoted the importance to take first a step back and look at the problems from 3TU ICT architecture according to the three steps as discussed in paragraph 3 [23]. With respect to the interoperability issues, a number of open standards are considered as a basis for the exchange of digital learning information between the digital learning environments at the three locations including:

- IMS (Instructional Management Systems) standards for the exchange of learning materials, student information, reviews and metadata;
- SCORM (Sharable Content Object Reference Model) for the exchange of web-based learning materials based on the XML standard;
- XCRI (eXchanging Course-Related Information) for the exchange of course and curriculum information and programme time schedule information [24].

Fig. 6 Common 3TU GS information portal

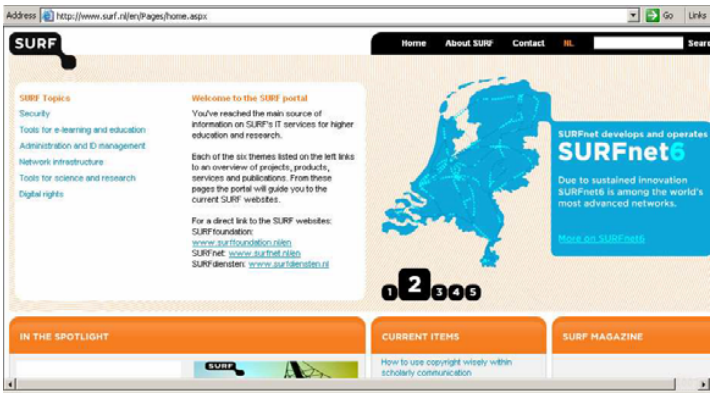

Fig. 7 SURFnet6 network portal

The main idea is not to replace the existing digital learning environments but to integrate them in such a way that they work together as a single 3TU digital learning environment with a common interface from which students can follow courses independent from location (and time). In 2007, the ICT&E group proposed reference architecture for a future 3TU digital learning environment based on the Service Oriented Approach (SOA). In this context, SOA is used as a container term which refers to technologies and concepts such as business process modeling and redesign, middleware technology and web technologies and standards. However, at the time writing of this paper, a common 3TU digital learning environment is still a long term ambition and its development is lacking progress due to financial and technical, but moreover, political reasons. Till now, only a common 3TU GS information portal have been developed offering some general information (e.g. course structure, admission requirements, contact information etcetera) about the 3TU MSc curricula (Figure 6).

For the short time, a number of temporary and pragmatic technical solutions are provided by SURF, which is the higher education and research partnership organization for network services and ICT in the Netherlands. SURF exploits a hybrid network (SURFnet6) and offers innovative services for security, authorization, middleware, identity management, groupware and videoconferencing. In this academic year (2007/2008), also Microsoft Sharepoint Portal technology provided by SURF (SURFgroups) has become available for the exchange and central collection of learning materials (Figure 7) [25].

From a short evaluation about the uptake of the additional digital learning technologies and tools provided by SURF during the first semester of the MSc CME programme, the following conclusions can be derived:

- Both teachers and students prefer to use the functionalities of their local digital learning environments with which they are familiar with above the advanced and additional functionalities provided by SURF;
- In cases students from different universities have to work together, on for example a project, students use traditional communication tools, such as telephone and e-mail, to discuss and to exchange information instead of using the collaboration tools provided by SURF;
- Sharepoint Portal technology is only used in one specific course. However, this technology was not provided by SURFgroups but based on the existing course ICT infrastructure at the TU/e;
- Although SURF provides single-sign-on and other functionalities to support students to access digital learning environments from other universities, the differences between these environments (e.g. differences in invoking functions, navigation structures et cetera) hampered the use of native digital learning environments by non-native students.

VI. The Parametric Design Course Case

The Parametric Design course is offered to the students as an elective course in both joint MSc programmes as discussed above as well as in the regular Civil Engineering MSc programme at TUDelft. The Parametric Design course allows students to learn about the basic principles of computer graphics and in particular the development, implementation and application of parametric design systems. The theory is presented to the students as oral lectures where the students learn different theories, methods and techniques for modeling (including solid and product modeling and the Unified Modeling Language (UML)), storing (including object-oriented and relational databases) and the application of graphical information (including Computer Aided Design (CAD), parametric and feature design systems).

The practical part of the course (i.e. an individual exercise) is to develop and implement a parametric design system based upon the solid modeling functionality of an existing CAD system and to enhance its parametric design functionality by using Visual Basic for Applications (VBA). Although the students may have some skills in computer programming and UML, they are still offered three crash courses in UML, solid modeling (with AutoCAD) and VBA.

The problem with an elective course is its time schedule that in most cases coincides with obligatory courses, preventing students from being present during the lectures and exercises. At the TUDelft, Blackboard is used as the default digital learning environment to provide the students with the required documents related to the course. Following the experience with the ITC Euromaster, an experiment was conducted to tackle the problems facing the course of Parametric Design. The teacher and the students collectively agreed upon the most suitable time for the lectures (most students were at home). Some lectures were delivered in a traditional fashion but the ClickToMeet environment replaced the classroom (Figure 8).

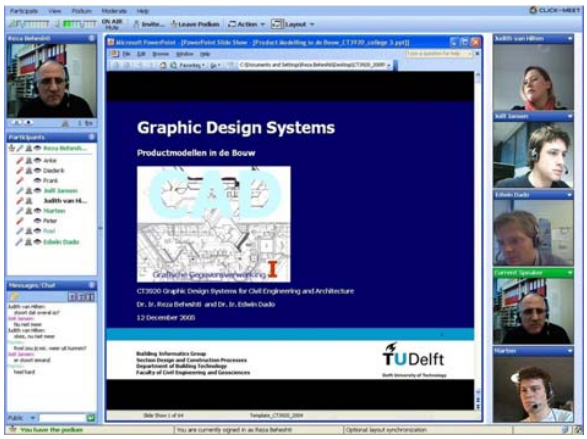

Fig. 8 Virtual classroom

The remaining lectures were recorded using MS Producer. These (digital) lectures were posted on Blackboard and the students were asked to prepare themselves, prior to the tutorial, at their own convenient time. The experiment showed that students were able to gain the required knowledge from these learning materials individually, because they all were able to formulate questions and discuss the content of the lectures during the regular tutorials. One analysis can be the concentrated attention of the student to the lecture that provided a focused look at the screen and being cut off from the outside noise by the voice of the lecturer in the headphone (Figure 9).

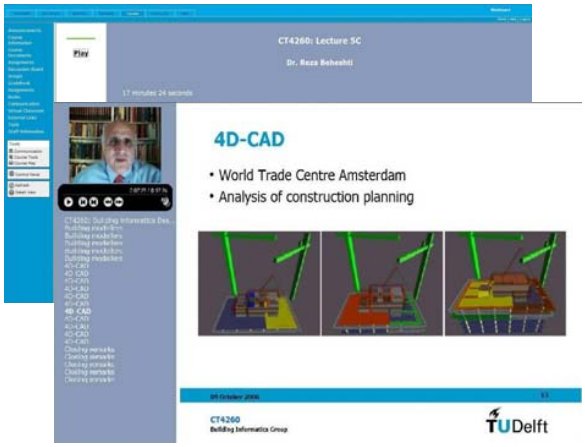

Fig. 9 Lecture recorded with MS Producer

As discussed earlier, the purpose of the exercise is to develop and implement a parametric design system by using an existing CAD system and VBA. The main idea was to develop and implement a parametric design system for factory buildings with which clients are able to analyze the optimum of value versus cost by only providing a limited number of basic dimensional (3D) and functional specifications (i.e. requirements). During the development process, students were able to discuss modelling and programming issues with the teacher and the student assistants by using the Discussion Board of digital learning environment and/or by using the virtual classroom during the regular scheduled discussion meetings (Figure 10). Only in a few cases, direct contact with students was required.

Fig. 10 Discussion meeting during the Parametric Design course

Compared with previous years the students gained a deeper understanding of parametric design systems. They were able to be engaged in group discussions and location independent work that necessitated acquiring additional information and knowledge with assignment results with higher quality and developed far beyond the course requirements. In addition the student experienced the proactive participation in the course and the individual time management as beneficial to more effective learning [9,11,26].

VII. Conclusions and Discussion

As discussed in this paper, there are many indications that ICT exert influence on improving the quality, flexibility and effectiveness of learning and teaching environments. Most probably digital learning (and teaching) environments which are capable of surmounting the barriers of time and location have become crucial to the availability, accessibility and acceptability of Continuous Learning and Lifelong Learning. The development of these digital teaching and learning environments requires thinking of a comprehensive strategy for the whole education sector, requiring rethinking of conventional face-to-face teaching and memory based learning. These strategies will define the course of actions to be taken in order to provide high quality digital learning resources as well as devising awareness procedures for discovering the value of personalized digital learning environments.

This paper examined attempts for making use of the available digital learning technology and tools in respectively the ITC Euromaster, (3TU) MSc CME programme and the Parametric Design course. Within the ITC Euromaster project, a fully operational digital learning environment has been established consisting of two main components: (1) a virtual classroom for on-line meetings and (2) a learning portal for enabling access to teaching and learning materials. Although the underlying technologies and tools of this digital learning environment provides some functionality to support open learning standards, it still can be regarded as very closed in the terms of the interoperability with administrative, student tracking, financial systems et cetera. From an end-user point of view, the established digital learning environment is very stable and well running. Except of some audio fine-tuning and (local) bandwidth problems at the beginning of the academic year, the lectures run perfectly throughout the semesters.

Compared with the ITC Euromaster, the main idea within the 3TU GS is not to replace the existing (and different) digital learning environments at the three involved universities but to integrate them in such a way that they work together as a single 3TU digital learning environment with a common interface from which students can follow education independent from location and time. The use of open (digital) learning and web standards is considered as a basis for this integration. However, a common 3TU digital learning environment is still a long term ambition and its development is lacking progress due to financial, technical and political reasons. For a number of reasons, the uptake of the temporary solutions provided by SURF within the MSc CME programme is very disappointing. It seems that both teachers and students prefer to apply their current knowledge about their local digital learning environments in stead of learning the new and more advanced possibilities of technologies and tools provided by SURF.

The outcome of the experiments made during the Parametric Design course coupled with the experiences from the ITC Euromaster programme delivered some significant findings. The application of a digital learning environment provided the students with greater degree of freedom and time management by allowing the student to study at his or her convenient time. This was possible through the use of a virtual classroom and recorded lectures. In addition, the digital learning environment paved the way for replacing the conventional face-to-face lectures (monologues) to dynamic discussions during tutorials (dialogues). Based on the outcome of the experiments made during the Parametric Design course coupled with the experiences from the MSc CME programme one can state that the commitment and enthusiasm of both teachers and students are crucial factors for the success, acceptability and usefulness of digital learning and digital learning environments.

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