Developing a European Master in Construction IT

E. Dado[1], R. Beheshti[2]

1) Assistant Professor. Delft University of Technology, Faculty of Civil Engineering and Geosciences, Design and Construction Processes, Building Informatics Group, Stevinweg 1, 2628 CN, Delft, The Netherlands. E-mail address: e.dado@ct.tudelft.nl / 2) Associate Professor. Delft University of Technology, Faculty of Civil Engineering and Geosciences, Design and Construction Processes, Building Informatics Group, Stevinweg 1, 2628 CN, Delft, The Netherlands. E-mail address: r.beheshti@ct.tudelft.nl

1. Introduction

Nowadays, information is probably the most important "construction material" in the Building and Construction (BC) industry (including Civil Engineering) [1]. Over the years, IT has changed the way people in the BC industry create and exchange information. IT can be defined as "the use of electronic machines and programs for processing, storage, transfer and presentation of information" [2]. IT encompasses many technologies such as computers, software, networks and even telephones and fax machines. Computers and software are used to create non-existing or change existing information (i.e. information processing) and networks, telephones and fax machines are used to make information available for others (i.e. communication) [3]. The term Construction IT has been accepted in the last few years to denote the specific field of applied IT in BC. A more concise definition of Construct IT is given in [4]: "Construction information technology is equipment, applications, and services that are used by organizations to assist human communication, commitment negotiation, problem solving and decision making, and is utilized over several civil engineering[1] disciplines".

Several surveys have been conducted in the past couple of years to determine the use IT in the BC industries of various countries [5, 6, 7, 8, 9]. Although, these surveys showed that there is a clear evidence of a widespread (and increasing use) of IT in the BC industry, the uptake of IT in the BC industry can be characterized as slow in comparison with other industries. However, it is expected that the uptake of (advanced) IT in the European BC industry will accelerate in the coming years. One of the incentives for this acceleration is the increasing pressure from society and market for improved competitiveness of the European BC industry. As stated in the influential Latham report in the United Kingdom, a significant part of the efficiency improvement can be associated with IT enabled process innovations [10]. In order to meet the future demands for IT-skilled students, universities have to complement the existing portfolio of teaching programs, incorporating IT knowledge and skills required for the BC industry.

The BC research community has already for decades emphasized the increasing importance

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[1] In the continental Europe, "civil engineering" is considered as the most generic discipline.

of IT for the BC industry. However, researchers still seem to live under the impression that they have all these fantastic solutions and the only thing lacking is a way to make the BC industry using them. Several EU research projects have tackled this issue from the perspective of educating the practitioners and tried to bring research results closer to the practice (e.g. SCENIC [11]) or asking the practice what is actually required by the BC industry (e.g. ELSEWISE [12]). Educating the practitioners is a good thing, but the real incentive for change is educating the students at the universities. After all, students are powerful agents of change when they are employed, and they can be a powerful technology transfer mechanism [13].

At the faculty of Civil Engineering and Geosciences in Delft, undergraduate students are offered general IT courses that introduce computer science, basic programming, Microsoft Office, AutoCAD and ARC/INFO. During the engineering courses they also learn to use computer programs that tackle a particular area, such as DIANA (i.e. a finite element program for computational mechanics), DUFLOW (i.e. a program for water resources modeling), PLAXIS (i.e. a finite element program for the analysis of deformation and stability in geotechnical engineering projects) and many others. The real problem lies in the fact that: (1) none of the above fits the definition of Construction IT, (2) this way of learning about discrete, unconnected software tools only widens the "sea" between the "islands of automation[2]" and (3) these programs do not educate students in an area where the potential of IT in Construction is the largest – in integrating this fragmented industry and thus providing a holistic perspective of the profession [14].

Based on the observations made above, a proposal for a European Master in Construction IT has been proposed by a consortium of nine universities and granted by the European ERASMUS/ SOCRATES program in 2001.

2. European Master in Construction IT

The main objective of the project was to develop a curriculum for IT in Construction to give students the possibility for extending their knowledge in the application of IT in the BC related disciplines. The curriculum is focused on students who have finished their undergraduate studies with a university degree in civil, building or structural engineering, surveying and construction. A roughly estimated average of 10 students per participating country per year would give about 50 students in the first year [15]. It is, however, expected, that the number will increase in the following years. The reason is that the BC industry with its related areas covers some 8% of the population in Europe. This point to the fact that there will be a need for more engineers with profound IT understanding as discussed in the previous section.

The curriculum should complement the existing portfolio of IT-education programs of the nine participating universities and must be able to meet the growing demand for such skills in the European Union. The current implementation consists of 12 taught units (subjects) and a dissertation element. The curriculum is being developed in such a way that courses will be offered from several universities in a conventional way (face-to-face) as well as in a web-based, distance learning form. It was planned to start the individual courses (as part of the existing programs) in the academic year 2003/2004 and to offer the complete European

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[2] Groups of operative systems that manage their operations properly and efficiently, but which are surrounded by gaps of non-interoperability.

Master for postgraduate students in 2004/2005. The integration with the current Master courses at the faculty of Civil Engineering and Geosciences in Delft is seriously considered by the faculty and probably will be offered as elective Master courses in the first instance in expectation of full accreditation of the program by the curriculum committee. In this regard next to the two courses offered by the Building Informatics group, all other courses offered by the European Master program can be presented locally based on the teaching materials of other partner universities.

2.1 The consortium

The consortium formation has complementary expertise and skills required for achieving the project objectives. Each of the participating universities has profound knowledge about one or more of the subjects in the proposed curriculum. Another major criterion in the composition of the consortium is the partners' experience in Construction IT related research. Many consortium partners have more than 20 years of experience in EU-funded research, covering almost every aspect of Construction IT. Table 1 shows the universities that joined the consortium (in alphabetical order).

Organization name (original language)	**Country**
Universidade do Algarve	Portugal
University of the West of England, Bristol	United Kingdom
Delft University of Technology (TUDelft)	The Netherlands
Technische Universität Dresden	Germany
Universidade nova de Lisboa	Portugal
Univerza v Ljubljani (project coordinator)	Slovenia
Univerza v Mariboru	Slovenia
University of Salford	United Kingdom
Bauhaus-Universität Weimar	Germany

Table 1. *Consortium formation.*

2.2 The proposed curriculum

As stated in de original project proposal, the curriculum will span the whole range of Construction IT including [15]:

- Technological aspects, e.g. operating systems, programming languages, computer networks and communication technologies and specialised hardware
- Theoretical aspects, e.g. numerical methods for the determination of physical behavior, relational algebra for database systems and graph theory for project management
- Models including their functionality, e.g. for numerical analysis, for project and construction management
- Processes including their simulation, e.g. in planning, financing, production and facility management

During the first phase of the project, a skill audit was conducted to determine the existing expertise available at the partner universities in each of the aspects of Construction IT as discussed above. Also each partner was asked to carry out a market survey in its respective country to identify the knowledge and skills required by the BC industries. At the end of this

phase, a course document was completed covering the (draft) course structure, course contents, delivery methods, assessment methods, marketing and recruitment strategies, and plan of the operation of the course delivery.

During the second phase of the project the course content has been developed. A project meeting was held to discuss the allocation of development tasks for all of the taught units, based on the expertise of each university as revealed in the first phase. Each unit was assigned to a leading university and optional assisting universities. The leading university was responsible for coordinating the development of the course content of the assigned taught unit. Table 2 shows the course structure consisting of 12 subjects.

Subject	Content	Lead	Partners
Role of IT in Construction	philosophy and history of science and technology, strategies, frameworks, paradigms etc.	Ljubljana	Bristol
Databases and data structuring	data structuring & retrieval, SQL, databases, security etc.	Maribor	Dresden
Information modeling and retrieval	information modeling & retrieval, classification systems etc.	Lisbon	Delft Dresden
Modelling and visualization	shape modeling, CAD, computer graphics, VR, simulation etc.	Delft	Dresden Maribor
Software engineering	practical project using much of the content from other subjects	Dresden	Ljubljana Delft
Engineering Artificial Intelligence	expert systems, neural networks, genetic algorithms, agents, etc.	Algarve	Dresden Lisbon
Knowledge management	fundamentals, principles, tools, paradigms, standards etc.	Delft	Dresden Ljubljana
Computer mediated communication	information mediation, protocols & mechanisms, Web Services, Semantic Web, etc.	Bristol	Ljubljana
Mobile computing	definition, virtual and real space binding, components, systems etc.	Maribor	Dresden
Computer integrated construction	project webs, concurrent engineering, distance working etc.	Bristol	Dresden Ljubljana
Virtual enterprises	methods and technologies to enable the development and maintenance of virtual enterprises	Lisbon	Algarve Dresden
eBusiness	B2B, B2C, C2B, legal issues, digital signature, privacy etc.	Dresden	Delft Lisbon

Table 2. *Course structure.*

The courses will basically take two years and will be awarded 120 ECTS credit points (10 ECTS each). Each student has to accomplish nine subjects plus a Master graduation work of 30 ECTS. The curriculum will be offered either as a new studying program or it will be included in the relevant existing programs, depending on the partner's current situation and the higher education system of the respective country. Most partner institutions, however, will offer a new postgraduate program on Construction IT, giving a "European Master on Construction Information Technology" as the postgraduate academic degree. The European

Master on Construction IT will enable students either to continue as PhD students or will work in the BC industries as engineers with a specific focus on Information Technology.

2.3 Course delivery methods

Once the courses are developed, they will be taught through a combination of face-to-face teaching and Internet-based distance learning teaching methods. Students will register with each individual university and will study the taught units offered at their own university through the well-established mode of delivery prevailing at the university. In addition, the students will study taught units offered by other partnering universities through Internet-based distance learning complemented by lectures delivered by visiting academics. In this way the accessibility of courses will be maximized. Students will also have the opportunity for visiting other partner universities during the course of their study. This will provide them with a flexible and interesting learning experience, as well as getting more familiar with engineering methods, technologies and culture of specific countries [13].

At the time of writing, it is expected that the distance learning facility will be operational in the academic year 2004/2005. The distance learning delivery will be based on the model pioneered at the University of Salford in its Internet distance learning courses [16]. The distance learning arrangement will enable the partnering European universities to share teaching and learning resources and will provide their students with a high quality European wide Construction IT curriculum.

3. Implementing and merging with the existing program at the TUDelft

During the project, each partner was responsible for seeking approval at its own university to run the joint Master in Construction IT. At the TUDelft, however, it was decided not to run the program, for the time being, as a separate new postgraduate program on Construction IT, but to merge the outcome of the project with the existing IT-education curriculum at the Faculty of Civil Engineering and Geosciences (Building Informatics program).

TUDelft is also actively engaged in efforts to implement fully the eLearning/eTraining in the curriculum. To pursue this policy, TUDelft opted for implementing the Blackboard as its eLearning engine throughout the university. This choice was made after an initial investigation of available tools and methods. The choice was also based on some initial experiments involving a limited number of courses. The experiment also revealed the course requirements for such environments. Presently the Blackboard is fully implemented but its use by the courses is gradually increasing. One problem also relates to the fact that TUDelft, in response to Bologna Agreement, implemented a new education system requiring the Master courses to be given in English. Also, there is a gradual increase in using digital material for the courses such as PowerPoint presentations, digital course books and alike. Therefore TUDelft finds itself in a transitional period for not only the implementation of new technologies but also at the crossroads for changing from the traditional teaching methods to some new ways of knowledge transfer and Internet -based distant learning forms.

The Building Informatics Group[3] participated in the above mentioned experiments, being one of the first groups offering limited use of the Internet for students following its courses (e.g.

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[3] This group is as January, 1st 2004 merged with the Design Management to form the 'Design and Construction Processes' group at the Faculty of Civil Engineering and Geosciences in Delft.

online registration, online PowerPoint presentation of lectures and some downloadable course materials). Amongst others the group participated in an eLearning experiment involving 5 European institutions. The research co-operations of the group also led to some common courses of 5 European partners on modeling in the field of river design. The following universities participated in this experiment: universities of Cottbus (Germany), Grenoble (France) and Budapest (Hungary), IHE (Delft) and TUDelft. The students of the course, from different countries, co-operated in the same exercise. The international teams communicated and collaborated via the Internet, email and used ftp server provided for the experiment. They ran models that are located at one of these research groups. This experiment was part of a research project on a web-based virtual campus initiated by the group to design and develop some distant learning and design tools using the latest available technologies [17]. The experiment was a success in the sense of providing some feedback on practical implementation and limitation of such technologies. For instance we still have some problems with running software and templates while the current technology developments point to the possible solutions (e.g. web-enabled software).
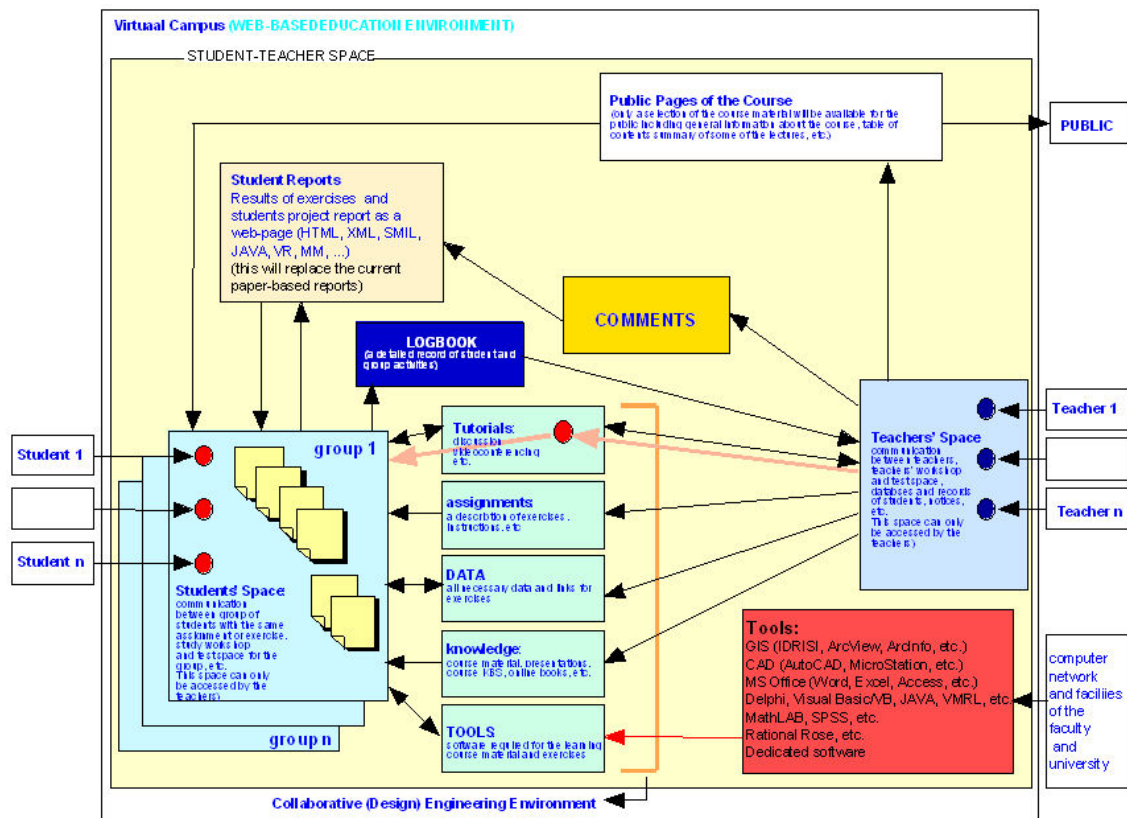

Figure 1. *The initial idea for a Web-based virtual campus.*

In the meantime, TUDelft participates in the European Master program for Construction IT described earlier. At present the faculty of Civil Engineering and Geosciences studies the possibility of including all courses of this program (as soon as they are available) into the elective part of the curriculum. The faculty expects the local version of these courses to attract the students who are following local master classes at the university. In this regard, this may also help more students attending the European Master program. Nonetheless, only

a fully implemented distant learning facility can guarantee the success of this program that probably requires a great degree of student proactive participation in the program, using the self-study and interactive course materials.

The research program of the universities involved plays a significant role in the web-enabled educational program. The impact of the research on Master's education can point to the following aspects:

- Knowledge that is generated in the research is introduced in master level courses where advanced modeling and information systems are integrated into the curriculum.
- Tools that have become available as spin-off during the research can be used for master level courses as educational tools. Presently, some of these products are used by various research projects such as a recent computer program developed as a tool for designing mooring systems for offshore platforms.
- Also these courses can be advantageous to the graduation thesis of Master students by providing them with the latest knowledge on Construction IT developments. This is also useful for the research activities of the group as well as being some valuable experience for students graduating with specialization in Building Informatics

The group also contributes to the post-academic education program (PAO) that is intended for offering refreshing courses for professional in the BC industry. The advantages of web-enabled course materials are increasingly evident for these courses. In these eLearning / eTraining program the state-of-the-art of research can be presented to practicing professionals. These will be embedded in an overview of the fundamental and practical aspects of the methods that are covered by these courses.

"The research activities of the universities involved will have a profound influence on the quality, efficiency and effects of the program for a web-enabled distant education (eLearning/eTraining). The knowledge generation and transfer will address the crucial factors influencing the supply of affordable and acceptable eLearning/eTraining delivery and services. The current state of eLearning/eTraining research has been largely confined to technological fields through producing general solutions for capturing knowledge and its representation and to pedagogical fields investigating eLearning/eTraining effectiveness of various modes of delivery and services. The aim of the research agenda is to investigate the technological, organisational and pedagogical aspects collectively, by all involved universities, in the context of learning within the BC industry. The critical factors in embedding eLearning/eTraining delivery and services are the pedagogical and organisational dimensions. Furthermore, the agenda will be motivated by the recognition that the knowledge capture and representation and the resulting quality of the learning experiences and outcomes are not free of context but depend intrinsically on the properties of the working situation in the BC industry that is continuously varying over the time. The world view premise of learning based on individuals engaged independently on static materials will be ineffective in a context, such as the BC industry, where the pressing skill needs are for co-operative engagement on dynamic, variable and unforeseeable challenges.

A unique model of project-based work involving large-scale collaborations on repeated prototypes characterizes the BC industry. Further, the (European) BC industry is facing new emerging challenges on sustainability of energy and environments, European co-operation, pan-European codes and standards (probably the withdrawal of National codes and

standards), the challenges of globalization, et cetera to make the BC industry and related sectors competitive and innovative industry.

6. Conclusions

In July 2001, the Building Informatics Group of the faculty of Civil Engineering and Geosciences at the Delft University of Technology joined the ERASMUS/SOCRATES project that its main objective is to develop a European Master course in Construction Information Technology (IT) to complement the existing portfolio of IT-education programs of the nine participating universities in order to meet the growing demand for such skills in the European Union. The intended outcome of the project is a curriculum for students who have finished their undergraduate studies with a university degree in civil, building or structural engineering, surveying and construction. At present, most of the development work has been done and the accreditation processes at the different participating universities are in motion. This paper discussed the urge for a European Master curriculum in Construction IT in an industrial and educational context. The paper also discussed the development process and outcomes of the European Master in Construction IT, together with the current implementation of the outcome in the existing IT-education curriculum at the faculty of Civil Engineering and Geosciences in Delft.

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