How to Teach Computing in AEC

Karsten Menzel[1], Danijel Rebolj[2], and Žiga Turk[3]

[1] Professor, University College Cork, College Road, Cork, Ireland
K.Menzel@ucc.ie
[2] Professor, Faculty of Civil Engineering, University of Maribor,
Smetanova 17, 2000 Maribor, Slovenia
danijel.rebolj@uni-mb.si
[3] Professor, Faculty of Civil and Geodetic Engineering, University of Ljubljana,
Jamova 2, 1000 Ljubljana, Slovenia
ziga.turk@itc.fgg.uni-lj.si

Abstract. Information Technology in Architecture, Engineering and Construction (IT in AEC) is a niche topic, lacking critical mass in most faculties. Researchers are creating critical mass by intense international collaboration. The same is true for education about IT in AEC where critical mass can be achieved in a similar way. In 2004 the first students entered a new postgraduate program called IT in AEC. The program was developed by seven European universities. It is unique not only because of its content, which covers various related IT-topics, but also in the ways in which it is organized and executed and the didactic methods used. It is based on a commonly agreed upon curriculum and is delivered using distant learning technologies. In the first part, the paper describes the reasons for developing the new program. The second part of the paper describes the development process of the program and its content. The final part of the paper describes the learning environment and the underlying teaching-learning scenario(s).

1 Motivation

Information Technology in Architecture, Engineering and Construction (IT in AEC - sometimes called Construction Informatics) is a mature research field with a dynamic and growing body of knowledge (Turk 2006). However, the impact of this research on construction practise has been limited (Froese 2004). This impact is generally achieved through three mechanisms: (1) developments for products (such as software that embeds that knowledge), (2) standardisation and best practise that prescribe the knowledge to be used in the industry and most importantly (3) education (Turk 2004).

Generally, curricula development has not followed the results of research- the range of information and communication technology in Civil Engineering curricula, for example, is incomplete and often restricted only to skills related to the use of technology (Table 1 “Heitmann”). Therefore, traditional teaching and learning scenarios need to be re-shaped, interconnected and extended to meet the needs for specialized civil engineers with deeper IT knowledge in the AEC-industry (Table 1 “ASCE”).

Surveys and experiences show (Rebolj and Tibaut 2005) that the share and content of courses related to computer science and IT in undergraduate civil engineering

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curricula varies considerably from university to university. Typically, there are general introductory courses, programming courses and specialized courses in IT applications like the design of building models, technical drawings, finite element and heat loss programs for the determination of physical behaviour, information systems to support construction management and systems for enterprise resource planning.

However, the courses are mostly unconnected and only provide limited knowledge about the specific aspects of computer science and IT. There is little understanding of the holistic potentials of today's Information and Communication Technology (ICT). Such a way of learning about discrete, unconnected software tools does not properly educate in an area where the potential of IT in construction is the largest- in integrating the fragmented profession. "*Often there are gaps in modern engineering curricula regarding computer science. ….. However, many engineers believe inaccurately that computing is only a skill to be acquired on the job, not also a science to be learnt in an academic setting. Nevertheless, most will agree that there is a growing lack of correlation between what is taught ….. and how engineers use computers in practice*." (see Smith 2003).

According to the research conducted by Heitmann (Heitmann et al. 2003), academic requirements for all engineering programs at the Bachelors' level should contain the following IT-related abilities to:

- use common computer tools to produce documents and make presentations
- develop system models to carry out calculations and simulations
- design and maintain simple Internet work-space to support interactive teamwork
- computer-based tasks using object oriented programming and expert systems
- use professional computer codes to prepare data, obtain reasonable results from calculations and to verify results from an "engineering" point of view

The Master level should add the ability to:

- understand algorithms, their limitations and requirements, prepare the data for processing with professional code and analyze obtained results.

Due to the concern of appropriate computing component in the curriculum, the 'American Society of Civil Engineers' Task Committee on Computing Education of the Technical Council on Computing and Information Technology conducted a series of surveys in 1986, 1989, 1995 and 2002 to assess the current computing component in the curriculum of civil engineering. Key findings of the latest study (Abudayyeh 2004) include:

- the relative importance of the top four skills (spreadsheets, word processors, computer aided design, electronic communication) has remained unchanged;
- the importance and use of geographic information systems and specialized engineering software have increased over the past decade;
- the importance and use of equation solvers and databases have declined over the past decade;
- programming competence is ranked very low by practitioners; and
- the importance and use of expert systems have significantly decreased over the past decade.

Table 1. Competence Areas and Importance of Educational Programs in AEC

	Heitmann[1)]	Smith	ASCE[2)]
Common tools (spreadsheet, word processing, presentation)	Bachelor	n.a	High
Programming and underlying concepts	n.a	B ~)	Low
Computer Graphics, Geometric Modelling (GIS, CAD)	B*)	B ~)	High
Data preparation, evaluation	B*)	n.a.	n.a.
Modelling, calculation, simulation (databases, equation solvers)	B*)	B ~)	Medium
Expert systems (search techniques, case-based reasoning, model based reasoning)	B*)	B ~)	Medium
eWork, CSCW (web-technology, workflow management)	B*)	+)	High
Understand, evaluate, and select algorithms	Master	+)	n.a.
Design, operation, maintenance of software (Requirements engineering, complexity analysis, reverse engineering)	n.a.	B ~)	n.a.
Ubiquitous Computing	n.a.	+)	n.a.

Legend: B=Bachelor Curriculum *)=application level ~)=Smith 2000 +)=Smith 2003
[1)]=see Heitmann et al. (2003) [2)]=see Abudayyeh et al. (2004)

2 A Postgraduate Course Pool on It in AEC

Undergraduate courses and graduate programs in the area of IT in AEC are offered in Germany, Sweden, Denmark, The Netherlands, Switzerland, Austria, the USA, Canada, Australia and New Zealand. Turk and Delic (2003) developed a proposed core undergraduate curriculum for the Bologna undergraduate model. At the graduate level, team oriented, project-based scenarios are used in several distant education courses in AEC. The best known course is Stanford University's P^5BL Course, which has been running for a decade now (Fruchter 1996). Most of these courses force students to use information and communication technology in order to learn the underlying principles of IT in AEC (Menzel 1997, Bento et al. 2004). The maturity of these topics has been proven by some excellent books with engineering examples and exercises (Pahl and Damrath, 2000; Raphael and Smith 2003).

IT in AEC is still a new topic which is rapidly developing. In research, critical mass was achieved by creating international, collaborative research projects. To spread the research results through teaching, the same kind of critical mass had to be achieved. Forces have been joined to develop an international, multi-institutional postgraduate program (ITC Euromaster 2005). In 2001 seven European universities started to develop a new postgraduate program in IT in AEC. The program development was funded by the European Commission through the Socrates / Erasmus framework between 2001 and 2003, and again in 2004 and 2005 when two more partners joined in the program dissemination process.

The main purpose of the ITC-Euromaster project was to develop a commonly agreed upon curriculum in IT in AEC. This curriculum should complement the existing portfolio of teaching programs and should meet the growing demand for IT-skills in the AEC-sector. The development of the individual modules in the curriculum was coordinated by a responsible partner institution. Teaching materials have been prepared in digital form, conforming to available e-learning standards, such as SCORM.

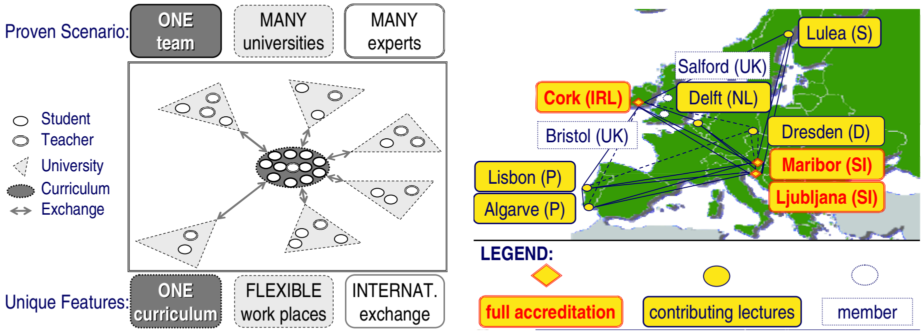

Fig. 1. Scenarios, Features and Partners of the ITC-Euromaster Network

Based on the results of a skill audit, the review of existing courses at partner institutions, as well as market research and analysis, a course structure has been developed consisting of 12 subjects (as listed in Table 2).

Table 2. ITC-Euromaster course pool: the commonly agreed upon curriculum in IT in AEC

INFORMATION MANAGEMENT	KNOWLEDGE
1. The role of construction informatics	6. Knowledge management
2. Data structuring and databases	7. Engineering artificial intelligence
3. Information modelling and retrieval	COMMUNICATION
4. Geometric modelling & visualization	8. Mobile computing in AEC
5. Software engineering	9. Computer mediated communication
	BUSSINESS / MANAGEMENT
	10. Virtual enterprises
	11. Virtual construction
	12. eBusiness and Data Warehouses

The curriculum is focused on students who have finished their undergraduate studies with a university degree in civil, building or structural engineering as well as architecture. The program graduates will earn a new “European Masters in Construction Information Technology” academic degree, which shall enable them to continue with the relevant PhD study or immediately start to work in the industry as civil engineers with a specific focus on Information Technology. Organization of the program called for inventive methods as well. Students enroll at each university, but they enter a single virtual class with teachers coming from the different partner universities (see Figure 1).

3 Applied Principles of Teaching and Learning

Since the creation of the Open University (London, 1969), "open", "distance", "flexible", "resource based" and "distributed learning" have expanded dramatically all over the world. The era of "e-learning" begun in the late 1990s. E-learning is now at the top of the agenda of public and private universities worldwide because it has the potential to change education and training radically, to open new ways of learning and to increase the ability of people to acquire new skills. From the functional point of view, there is a widespread acceptance that a holistic e-learning solution comprises three key elements (Henry 2001):

- CONTENT: adds to the knowledge, skills and capabilities of the human capital.
- TECHNOLOGY: comprises the infrastructure, management systems and learning technologies.
- SERVICES: include consulting, support, as well as design and build services.

Design, construction and implementation of eLearning scenarios aim at the optimal support of different methodological scenarios. In Figure 2, teaching methods are classified into three main groups: Presentation, Interactive Teaching and Independent Work. These teaching methods can be applied to realize different teaching strategies, such as 'didactica magna' (Comenius 1657), 'visiual instruction' (Pestalozzi 1801), 'advance-organizer strategy' (Ausubel 1960), 'basic-concept strategy', 'establishment of networks' or 'teaching of schemata'. (For complete references see Steindorf 2000).

Kolb (1984) provides one of the most useful, descriptive models of the learning process. This model suggests that there are four consecutive stages: Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC) and Active Experimentation (AE). Based on these four stages, a four-type definition of learning styles was developed for which Kolb introduces the terms: Diverging (CE/RO), Assimilating (AC/RO), Converging (AC/AE) and Accommodating (CE/AE).

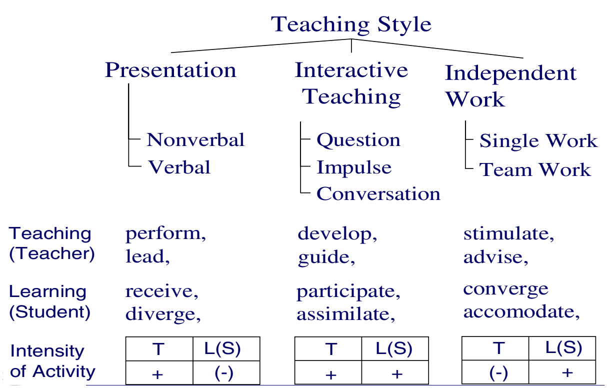

Fig. 2. Teaching Styles and related Teaching-Learning Activities

The different teaching methods and teaching-learning principles depicted in Figure 2 require different levels of ICT-support. For each of the categories, different levels of ICT-needs can be defined and are applied to the ITC-Euromaster framework as summarized in Table 3.

4 Collaborative Networks Within the ITC Euromaster Framework

Teaching on the Web induces different social and collaborative processes to the traditionally time-bound, place-bound and role-bound education models. Collaborative learning tries to create a virtual social space that must be managed for the teaching and learning needs of the particular group of people inhabiting that space. In an ideal collaborative learning set up, a student will know a great deal about his fellow students and faculty before he begins working through the material. He will be prompted with questions that have been very carefully designed to encourage him to link the material he is learning to his own knowledge and experience, as well as stimulate him to interact with other students and faculty. This model will use a database underlying the course management system to link people and information in new ways that will help them to understand the community of learners they have joined, as well as affect their relationship to the material itself.

Therefore, the current ITC Euromaster e-learning environment consists of two components: the Course Management System (CM), which is the entry point to the program (ITC Euromaster 2005), and a Virtual Classroom (VC).

Table 3. ICT-support for different teaching styles within the ITC-Euromaster network

Teaching Method: *ICT-support*	**Presentation**	**Interactive Teaching**	**Independent Work**	**ITC Euromaster**
Degree of Organization	scheduled, prepared	scheduled, improvisation	not scheduled, spontaneous	
PRESENTATION (nonverbal, verbal)				
Presentation devices	(++)	(++)	(-/+)	VC
Shared information	Read	Read / (Write)	Read / Write	CM
Audio transmission	UniDirectional	BiDirectional	BiDirectional	VC
Video transmission	BiDirectional	(+)	BiDirectional	VC
QUESTION:				
eForum	(--)	(-/+)	(++)	CM
eVoting	(--)	(+)	(--)	n.a.
Chat	(--)	(-/+)	(++)	VC
IMPULSE				
Messenger	(--)	(-/+)	(++)	*)
CONVERSATION / TEAM WORK				
Red-lining capability	(--)	(++)	(++)	*)
Shared application	(--)	(--)	(++)	VC

Legend: (--) not required; (-/+)recommended; (+) highly recommended; (++) required
VC: Virtual Classroom; CM: Course Management System; *) Windows components

The main function of the CM is to enable access to teaching and learning material, as well as other relevant functions (e.g. forums) and information (teacher and student list, timetables etc.) from the Internet. The course management system is based on the Modular Object-Oriented Dynamic Learning Environment (Moodle 2005).

The VC is supported by the ClickToMeet videoconferencing system, enabling teachers to directly communicate with their classes. A participant list, chat, audio and video control, document sharing, application sharing and a whiteboard are the basic parts of the VC. Both systems are interlinked and can be used as an integrated system.

There is no specific electronic tool or methodology to assess the students' learning progress or teachers' performance. Lecturers organize short tests during lectures and seminars. Students deliver the test results by eMail as electronic documents. Essays and theses are delivered by the students and commented on by the supervisors in an electronic way. Final exams are prepared by the responsible lecturer. The exam itself is organized locally by each participating university and monitored by local lecturers or teaching assistants. At the end of each teaching period, questionnaires are handed out to the students in order to get their feedback with regards to teaching style, performance of the ICT-infrastructure, etc.

5 Conclusion

At the University of Maribor and the University of Ljubljana, the program was accredited in 2004. Since January 2006 University College Cork has become the tenth member of the ITC-Euromaster network and accredited a 12-month postgraduate master program on "Information Technology in Architecture, Engineering, and Construction," using most of the ITC-Euromaster modules (http://zuse.ucc.ie/master). The other partner institutions are either in the accreditation process; or, the integration of the new program into existing programs is in progress.

The ITC-Euromaster network and the ITC@EDU workshop series are the two basic elements to support sustainable, further development of the ITC-Euromaster framework. The ITC-Euromaster network has managed the programme organization since 2004. It has organized the transition process from an EU-project into a self-sustaining course pool after the EU-funding period ended in the middle of 2005. All project members have signed a common "course pool agreement".

Since 2002 the ITC@EDU workshop series has proven to be a stable platform to maintain the discussion process amongst the members of the ITC-Euromaster network, external advisors and international partners. Through the workshops, the internal discussion process is stimulated and feedback is given by external experts to the network members, contributing to the continuous refinement and improvement of the program content, the "delivery" mode and the ICT-infrastructure of the ITC-Euromaster program.

With ten partners and three program accreditations developed out of the EU-funded ITC-Euromaster project, our network has developed the necessary critical mass to promote "IT in AEC" as an interdisciplinary scientific discipline. It has also substantially contributed to the sufficient transfer of knowledge and technology from academic institutions into the different areas of the AEC- and FM industry.

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