

Information and Communication Technology for Supporting Civil Engineering Education

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Abstract — *The increasing speed at which information becomes obsolete, and the rapid changes in the means by which information is delivered and renewed, is requiring the higher education sector to develop new strategies that are supported by Information and Communication Technology (ICT). These strategies aim at preparing a new generation of students that is better qualified to the new needs and challenges of the knowledge society. Similar issues are at the heart of many initiatives to restructure existing programmes and it is possible to find, in specialised literature, reports about successful experiences where the use of ICT has contributed to raise the quality and efficiency of academic and administrative services. This paper describes advantages and limits of the use of actual ICT mechanisms for learning/teaching considering previous experiences of the authors. Some ICT mechanisms are going to be analysed according to communication, cooperation and coordination aspects, which are important aspects in learning. Then, we present a proposal for the use of ICT mechanisms considering a civil engineering course.*

Index Terms — *Civil Engineering Education, Information and Communication Technology.*

INTRODUCTION

Life in modern society makes new demands on the individual's professional competencies and civil engineers are no exception. As a result, the university must not only provide these new competencies in the formation of its students but at the same time must encompass the continuous development of science. In addition, new educational policies and funding problems are also impelling changes. Therefore, all these new challenges cannot be addressed by simply altering content in the curriculum of existing courses, since it is not only content but also the way content is explored that should be revised. In addition, the spread of technology in daily life is also raising the students' expectations and they will demand more from the university than simple online access to content. These are the most significant issues that are forcing the higher education sector to develop new strategies supported by Information and Communication Technology (ICT).

ICT can contribute in several ways to the learning process:

- it can provide instructional content in ways that better stimulate students' motivation;
- it can ensure the independence of education from time and place; and
- it can be used to assure collaborative learning.

Collaborative learning refers to an instruction method in which students at various performance levels work together in small groups towards a common goal. As stated in Gokhale [1], collaborative learning fosters the development of critical thinking through discussion, clarification of ideas, and evaluation of others' ideas. This is a key issue as the advances in technology and changes in the organizational infrastructure put an increased emphasis on teamwork. Workers need to be able to think creatively, solve problems, and make decisions as a team. That is why the development and enhancement of critical-thinking skills through collaborative learning is an important goal of the educational process. Therefore, using ICT will contribute to better prepare students to the new needs and challenges of the knowledge society.

Although engineering programs are among the most affected ones by the ICT evolution, the reported experiences are more oriented to how ICT is applied to solve specific civil engineering problems or project's needs. Experiences on how ICT can improve the pedagogical aspects of the educational process are usually generic and do not address specificities of civil engineering. In the cases that relate ICT to improve civil engineering education, there is a strong bias to a certain topic and/or discipline. The main goal of this paper is to present a proposal for the use of existing ICT for learning/teaching on an existing civil engineering course in a broad perspective.

As we are proposing the use of ICT to support the education process in a civil engineering course, it is important to understand the specificities of this area. It is generally accepted that the essential knowledge base of a civil engineering programme includes: a strong foundation in mathematics and physics; a good understanding of the principles of engineering science, economics, business and management; broad background of the different branches of civil engineering and a deeper understanding of a specific professional area; some education in environmental matters, and introduction to ethics. During their course, students need to develop some important skills which include: problem solving and design skills; team work and leadership skills; and communication skills. Besides students must also learn 'how to learn' in order to be able to cope with the continuous development of science and technology.

In the next section we briefly describe and discuss the use of existing ICT mechanisms to support learning/teaching and how they can contribute to enhance students' skills. After that we describe the authors' experience at PUC-Rio and generic guidelines for using ICT facilities. Then we propose a strategy to use these mechanisms in the civil engineering course at DECivil/IST, Technical University of Lisbon. Finally, we present some concluding remarks.

ICT TO SUPPORT LEARNING/TEACHING

Information networks and the Internet technology are offering new opportunities to organizations as they provide better communication with their public. This communication is usually supported by software systems that use Web browsers acting as user interfaces and providing access to data that may be stored in traditional databases or in a less structured manner. This is quite convenient. End-users access data through the widely spread browsers technology avoiding the need to distribute specific software in order to provide access. It is also possible to inter-link different media like voice, text or video in a simple way. Therefore it is possible to notice a general movement towards the use of Web pages as an entry point to the information systems. This trend is also noticed in the universities, where it is possible to perceive three main application areas when considering the use of ICT in higher education: administrative area; courses creation and development area; and courses deployment area.

Administrative area

Generally this area is where ICT is already extensively used. Almost all the universities have academic information systems to deal with activities like students' admission and enrolment, academic registry and course information. Following the existing trend these systems may be accessed by a Web page where general information about the university is also published. As these systems usually have a minor impact in learning/teaching we will not further discuss them in this work.

Courses creation and development area

There are now several tools for supporting the creation and development of content for the courses. They are html authoring tools, word processing, presentation tools, video recording and edition etc. As the Web is now a commonly used media, some of these tools have facilities to enable publishing on the Web and it has been common practice to put class notes and homework assignments in Web pages.

In addition, the development of visual simulations and the creation of virtual laboratories where students can do experiments and observe the results using computer animations are also possible and there are many examples of such systems. Anyway, there is no doubt that these tools can enhance in a significant way civil engineering education as they allow students to conduct experiments and extensive parametric studies that can provide in a short time some of the experience and understanding about those phenomena that otherwise would be difficult to acquire. However, if these applications were developed without any concern about Internet technology then there may be problems of interoperability to use these tools in Web-based systems.

Other authoring method is related to grouping together pieces of instructional content [2] that are usually called learning objects (LO). This approach is essential to the creation of LO repositories that could be used to promote reuse of existing instructional materials allowing a cheaper and quicker process of content development. Although this is an interesting idea there are not yet generally available tools to support this approach.

There are other important activities to course creation, like the definition of the overall goal of a course or how content components should be organised that are not supported by authoring tools. There is a lack for an integrated system covering all aspects of course creation and development. The main reason is the inexistence of a structured and commonly accepted methodology for course development that would establish strategies, techniques and tactics to be applied considering existing learning theories and instructional approaches in order to make learning more efficient.

Finally, there is other group of tasks that are related to the development of educational and training content material. They imply on selecting media and producing material according to information design and learners' skills. It is expected that in a near future it would be possible to create content that afterwards will be used in different media according to students' preferences and abilities.

Courses deployment area

Course deployment involves dealing with a management plan, strategies and tactics for keeping learners interested on the subject and monitoring results. Since it is in the course deployment that the learner effectively learns, most of the available educational and training systems address only this phase. These tools are usually named Learning Management Systems (LMS) and they offer an integrated environment with a set of services to support learning/teaching.

When considering teaching, there are two main approaches. In the traditional model, information processing or symbol-processing approach ([3] and [4]) the key concept is that a teacher transmits a fixed group of information to the learners through an external representation or medium. The learners develop their own image and use it to construct new knowledge based on their own previous knowledge and abilities.

The other approach ([5], [6] and [7]) is based on constructivist principles, in which learners actively construct an internal representation of knowledge by interacting with the material to be learned. There is a high degree of interactivity among all the participants.

Educational and training systems based on the first approach, usually focuses on the access to content material in a previously specified sequence. Therefore it involves the access to the content and visualisation procedures. There are some proposals for sequencing material such as IMS Simple Sequencing Information and Behavior Model [10], while web navigational characteristics can be modelled according to proposals such as OOHDM [8].

Educational and training systems based on the second approach usually focuses on interactivity and, therefore in groupware concepts. Groupware concepts have gained importance when considering interaction/collaboration. According to the 3C model [9] a group support system need to provide support for Communication (i.e., information exchange), Coordination (i.e., process definition and scheduling) and Cooperation (i.e., working on shared tasks and accessing/manipulating shared data).

- Communication can be synchronous or asynchronous. Exchanging information is a crucial activity in learning/teaching and this justifies the importance of being able to take the best from the new communication possibilities offered by ITC.
- Coordination involves defining course agreement terms and rules as well as learning activities and their scheduling. It helps students (and also teachers) organise their tasks in time.
- Cooperation enables teamwork, allowing students to improve their social skills while learning. It can be as simple as providing different working areas to the development of tasks or as complicated as tracking changes, controlling concurrence and versioning.

Many of the existing LMS support tasks in these three aspects enabling a constructivist approach to learning. This approach is suitable for teaching subjects where knowledge is not so well structured like structural design or construction planning.

Another aspect usually covered by LMS is assessment. These systems offer tools for the creation and implementation of assessments that can be used not only for grading purposes but also to allow students to measure their comprehension about the related subjects. This kind of assessment is essential to automatically control the student's progress and can be used to give him advice when his knowledge does not satisfy a certain goal. Although there are now important tools for assessment there are still many open issues that limit its use when considering grading.

Many of the LMS tools can also be used in a less integrated manner to support teaching/learning. If a school does not possess a LMS it may also benefit from the advantages of using ICT to support course deployment as many of the functionalities offered by these systems are also available as common Internet services such as those that are discussed in the next topic.

AN E-LEARNING EXPERIENCE AT PUC-RIO

The authors have been engaged on several e-learning projects at the Distance Learning Centre of PUC-Rio over the last 4 years. Besides working with different educational software and discussing infrastructure for e-learning, the authors also have participated of web-based courses as well as face-to-face courses with some ICT component. These experiments have demonstrated the ICT potential to support teaching/learning.

At PUC-Rio, teachers have been able to compare face-to-face classes with online classes of the same subject and observed a deeper critical discussion at online classes. The same was observed when the e-learning environment was used to complement face-to-face classes. In addition, it was possible to witness that students were very motivated especially for the use of communication services to discuss topics.

The use of hypermedia navigational characteristics of the Web content was also found to be a valuable issue as, besides motivating students, it has facilitated the understanding of some subjects.

Although these results were very encouraging, it is worth noticing that there were also several obstacles that must be considered in order to have a successful result. First it is very important to have an infrastructure with enough capacity to deal

with the existing requirements not only in terms of hardware and software but also in terms of staff and technical support. The lack of any of these factors proved to be a major problem as failures related to the infrastructure usually conducted to high dissatisfaction and loose of motivation from users. Corroborating authors' experience other works report similar results ([11] and [12]).

Second, as teachers are usually involved in other activities and they are not open to change their methods, it is important to have an institutional strategy, which incentive their participation in this process. Moreover, it is important to assure teachers' confidence in their ICT competence. Several studies refer to this aspect as being mentioned by teachers as the main reason for not using ICT ([11], [12] and [13]).

Third, it is quite difficult and expensive to develop high quality content. Therefore, it is crucial to have a development team with the required competencies and using a methodology to guide their work in order to be able to fulfil users' expectations. It is essential that there is an effective use of ICT to create innovative learning experiences as using ICT to imitate traditional classroom methodology will not really contribute to enhance learning [14].

Despite these problems the authors believe that it is worthwhile to adopt ICT and consider that the identified benefits can also be valuable when taking into consideration a civil engineering programme. To assist the use of existing Web technology in learning/teaching some guidelines are presented at Table I.

Proposed strategy for adopting ICT in civil engineering education at IST/UTL

The experiments conducted so far showed that students are open to the use of ICT and therefore the Civil Engineering and Architectural Department (DECivil) at IST/UTL is committed to adopt the Web as the main communication channel with students and also with professors. All the announcements to teachers and staff are through mailing lists and there is an effort to develop for every discipline within the department a Web page giving access to syllabus, agenda and other important information. It is expected that these actions will foster the use of ICT and stimulate the adoption of new teaching/learning strategies based on ICT.

Considering the experience gained at PUC-Rio, it is suggested to the DECivil that the decision about adopting ICT to complement traditional face-to-face courses is put to practice according to the following proposal.

Begin by establishing the infrastructure that will be used not only in terms of hardware and software but also on available human resources to support the needed activities. According to existing limitations, decide about technology to be used and define a chronogram for implementation tasks. It is also important to assure that the needed infrastructure will be available. As earlier mentioned, lack of resources has been identified as an obstacle in the way of introducing ICT in schools.

As it is expected that the majority of professors is not yet enough motivated to immediately embrace ICT to support learning/teaching in their disciplines and has not the necessary knowledge and skills, it is proposed to start gradually by disseminating the online culture in target disciplines and small groups of students.

As stated in [15] there are three conditions identified as necessary for teachers to use ICT:

- Teachers must believe that technology can more effectively achieve or maintain a higher-level goal than what has been already used.
- Teachers must believe that using technology will not cause disturbances to other higher-level goals.
- Teachers must have the ability and resources to use technology and believe on that.

Considering the previous conditions, the strategy to engage professors in the use of ICT should be based on the following issues:

- Creation of incentives to attract professors to actively participate in the process. It is important to show that the DECivil is committed to this process and willing to compensate professors' efforts.
- Creation of a pioneer group of professors to be selected among those who are the most interested to implement experiments. This group must have adequate pedagogical and technological support to develop online materials for their topics and promote learners' interactions within their disciplines.
- Prepare training sessions for all the professors in order to avoid possible lack of knowledge or skills.

It is expected that other professors perceive the increase of the learners' interest and understanding due the use of ICT and, therefore be willing to participate in the process. Then, according to the experience of the initial group of professors as well as the available resources, other professors will be involved until all the professors embrace this initiative, enabling more innovative educational practices and building a more critical thinking in the students.

An interesting side-effect that is expected from this approach is that the effort to digitalize and offer online access to content will show off possible existing consistency problems like duplication of topics or poor sequencing, which will lead to an easier revision of the curricula.

In addition it is proposed the creation of a Web site that will give access to all the content and other instructional tools available. This Web site would also offer other services to build an online learning community where students, professors and

staff will be able to communicate and interact, mapping and expanding the physical learning community that exists in DECivil. The main idea is to develop the users' sense of community as an outcome of working within an online environment designed to support the professional and personal development of its users. This is also expected to be an additional factor for motivation and engagement of all the members of DECivil in the use of ICT.

CONCLUSION

In this paper we have enumerated the main ICT tools available to support teaching/learning in higher education. Although we do not intend to fully describe all these tools, we expect that our approach helps on the understanding of their value to enhance learning, especially on civil engineering education. Civil engineering programmes can greatly benefit from the use of these tools as they support new constructivist strategies that enable the development of problem solving and design skills, team work and leadership skills, communication skills and last but not the least 'learn how to learn' that, as stated earlier, are essential skills to civil engineers.

The ideas presented as a strategy for DECivil may also be used in other environments and help other departments to take profit of ICT. The creation of a Web site with adequate functionality in order to build online learning communities will contribute not only to foster the use of ICT but also to establish and reinforce the relations between students, professors and staff.

It is important to understand that the use of ICT will impose a paradigm shift from the dominant educational philosophy that is essentially 'teacher-centred' to a 'learner-centred' focus. This paradigm shift requires earning with the following characteristics:

- High-quality multimedia learning materials produced by multi-skilled teams and available without time or place restrictions;
- Well-developed and fully-reliable infrastructure;
- Some form of tutoring the students in a personal basis; and
- Strong commitment to research on learning technology.

There is a new role for teachers that must become less a 'talking' head and more a facilitator of learning. In addition, they must be designers of learning experiences, processes, and environments in order to cope with the needs of preparing future engineers to solve open-ended problems with no unique approach and solution. This can be done by using collaborative work supported by ICT. Also, as civil engineering is a profession strongly linked to other professions like architecture or environmental engineering, the use of collaborative, team-based (desirably with students from different courses like architecture/structural/construction/environmental engineering) and project oriented learning with easy access to domain knowledge courseware will better prepare students to face real-life problems.

ACKNOWLEDGEMENT

The authors would like to thank the database technology group from PUC-Rio (TecBD) and the e-learning technology research group from ICIST/DECivil who actively participated on the discussions about ICT to be applied to Civil Engineering Education. This paper was partially supported by CNPq Brazil – Brazilian National Research Council, through a PhD bursary, and FCT Portugal – Foundation for Science and Technology, through the Multi-annual and Programmatic funds of ICIST.

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FIGURES AND TABLES

TABLE I

PRACTICAL GUIDELINES FOR USING WEB TECHNOLOGIE TO SUPPORT LEARNING/TEACHING

Purpose	Media	Guidelines
Content publishing	Web pages	Content can be published in Web pages with hyperlinks to other resources and may include audio and video clips or animations. There are two aspects that must be considered when designing Web pages: hyperlinks must be used judiciously in order to avoid that students get lost in the hyperspace and loose focus; bandwidth and estimated time required for accessing content should be defined according to the minimum identified user equipment capacity. That's why the use of video and audio should be analysed as there are still many speed limitations on the use of these media in Web context. When content includes especial features requiring long download times it is advisable to publish these items in CD-Rom and it is desirable to link these resources to existing Web pages.
Communication	E-mail	Using e-mail as a communication tool should be restricted to pose and answer personal questions that are not important for other participants. Ignoring this can lead to an overwhelming work to be able to give in time answers to participants especially if it is a numerous group.
	Mailing lists	It is used to communicate with the entire group and is important for sending acknowledgments. Mailing lists are not good for discussion purposes as messages are usually organised by date and it is difficult to find a specific topic.
	Newsgroups	This tool is very useful to promote discussions between the elements of the group. Messages are structured by topic in a hierarchical manner and it is very simple to find a specific contribution.
	Chat	It is a synchronous tool witch requires very well defined rules for being useful and some expertise in its use. Chat can be an interesting tool for socializing and build team relations. The use of chat in numerous groups is very difficult.
	Peer-to peer messages	These tools witch ICQ messages is the most known example are interesting as they allow group members to know the online presence of other participants and communicate immediately.
	Audio or video Conference	As in chat, using these tools requires very well defined rules for its use and are not adequate to numerous groups. As they require more powerful hardware they are not so common to use.
Coordination	Web pages	Web pages can be used for coordination purposes as they can be used to publish guides for student's activities, schedules, exercises, notes and other coordination information.
	Mailing lists	When some event occurs or there is a need to draw attention from the participants, mailing lists are very useful as it is possible to send coordination notes to the electronic post office box of all members of the group.
	Chat or other synchronous communication tool	When there are small groups these tools can be used effectively to discuss strategies and build consensus among the participants
Cooperation	Newsgroups	As they are useful for discussion purposes they can be use to promote cooperation between the participants and stimulate inter group aid.
	Chat or other synchronous communication tool	These tools can be used for discussing problems in small groups.
	Web pages	Web pages can be used in cooperation tasks if students are allowed to insert or update such documents.