TOWARDS A CONSISTENT ROLE FOR INFORMATION TECHNOLOGY IN CIVIL ENGINEERING EDUCATION

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ABSTRACT: For decades computers have influenced civil engineering education. Their role is significantly changed in due course of time in accordance with developments in both construction and information technologies.

At Delft University of Technology the role of information and communication technology (ICT) has not been identified as a separate subject for many years. This has resulted in a very fragmented usage of ICT in the current curriculum. Students learn to use applications such as AutoCAD, Matlab, Maple, Powersim, etc. in all kind of engineering courses. They are also introduced in information modelling with the modelling language UML and the modelling tool Together. And they learn programming in the Java language using the JBuilder programming environment. But these ICT topics are spread over the curriculum and a comprehensive view on ICT education for Civil Engineering is missing.

Recent discussions in the faculty regarding (1) laptops for all students and (2) the role of programming with Java in our study prompted a more fundamental discussion of these issues in a working group to discuss the role of ICT in civil engineering education.

This paper reports the findings of this discussion. First an overview is given of the ICT methods and tools currently used in the curriculum. These methods and tools are taught in a fragmented way. In addition, clear opportunities for integration of ICT methods and tools in relevant courses are hardly considered. An important factor in this context is the curriculum structure of the faculty that gives room to different courses to be developed and offered independent of other courses.

The paper also discusses the required objectives for civil engineering education. These objectives play a significant role in the formulation of proposals for improvements of the curriculum. The paper presents such a proposal devised for the improvement of ICT in the civil engineering education in Delft. Finally, findings and ideas are positioned in a broader context in an attempt to formulate some fundamental issues that are related to the education of ICT at any civil engineering faculty.

KEYWORDS: ICT, education, civil engineering.

1 INTRODUCTION

For decades computers have influenced civil engineering education. Their role is significantly changed over time in accordance with developments in both construction and information technologies. We have seen huge mainframes and terminals, punched cards, programming languages such as Algol and Pascal, archaic CAD-systems with keyboard input only etc. Nowadays we see PCs with Windows everywhere, laptops, languages such as Java, Visual Basic, but also still Fortran, CAD (though mostly 2D), a variety of tools used for specific purposes (Matlab, Maple, Powersim, etc.) and last but not least a students community that is used to broadband Internet at home, MSN, Google Earth etc.

It can also be observed that there is little coherence in the use of computers in civil engineering education in Delft. It is not uncommon that a technology or tool is learned in one course and never used again in another course. Civil engineering students in Delft learn Java (with Borland Together and JBuilder) but they often report that they never use it thereafter. Students use Powersim (a tool for modelling dynamic systems using stocks and flows) in their first year but hardly thereafter. Students learn CAD in their first year and apply it in design courses - but merely as a drawing tool. No attention is paid to the notion that they are creating and managing design information. Additional possibilities such as 3D CAD, 4D CAD and parametric design are only dealt with in small elective MSc courses.

To summarize the above: current use of information and communication technology (ICT) in civil engineering education in Delft is fragmented and incoherent. This is at least partly due to the overall fragmentation of the current civil engineering curriculum: many courses on all kind of subjects with little coherence.

Anyway, recently a working group was formed at our faculty, that investigates the future role of ICT in the civil engineering curriculum. An important motivation for this working group was the “students laptop issue”: higher

management had decided that all students should have a "university-approved" laptop in the future and preparation has started for implementation of this plan. Meanwhile, there was another issue concerning programming in the curriculum: the faculty had recently decided to terminate the last programming course in which Java was taught, and introduce a brief introductory course and a Matlab course instead. Many students and lectures reacted to this decision that programming should be part of the education of a civil engineer and should somehow return to the curriculum.

These issues prompted the working group to a more fundamental discussion of the role of ICT in the civil engineering curriculum. The goal of this working group is to formulate a coherent vision and policy on ICT in civil engineering education, including a proposal for revision of the current curriculum. The findings of this working group form the starting point of this paper (although the opinions expressed in this paper are opinions of the authors only; they are not necessarily the same as the opinions of the working group).

2 VISION: ICT AS A KEY TOOL FOR FUTURE CIVIL ENGINEERS

The starting point for any proposal for revision of the curriculum must be a vision statement on the role of ICT in the civil engineering domain. In our view, the role of ICT is already dominant in civil engineering practice, and this will even increase in the future. Maybe the most important role of ICT in civil engineering is that of enabler of *innovation*: improvements in civil engineering that go beyond gradual technical improvements, but that are related to radically new design or engineering methods.

It is almost unthinkable that such innovations will take place without ICT.

Examples of such ICT-driven innovative developments that can be observed in the construction management domain, are industrialisation of construction processes, supply chain optimalization and/or reversal, lean construction and increasing standardization in production/construction processes (see for example ManuBuild 2006 and ECTP 2006). In the building technology domain we see that complex structures, such as double-curved structures are increasingly designed with extensive use of ICT – it is not even possible to design such structures without ICT (see for example the so-called "blob-architecture" by Oosterhuis, 2007). These developments are to a large extend enabled by ICT developments in the area of parametric design, 4D CAD and nD-modelling (Kam et al, 2003, IAI 2007).

Another point that needs to be addressed is that current and future civil engineers are losing knowledge of what they are doing when they make calculations with computers. As a result they have more difficulty than before in judging the outcomes of computer programs; whether the results do or do not make sense. This phenomenon was already observed in the mid nineties, but it seems that the issue is still getting more important.

A final point is that a prominent role of ICT in civil engineering education in Delft will improve our image as a state-of-the-art, innovative school. This would be also an argument in favour of the student laptops (although we prefer to put specifications forward instead of university-approved laptops that are likely to be too expensive).

3 THE CURRICULUM

3.1 *General characteristics of the study*

In order to fully understand the issue of the role of ICT in our civil engineering study, the reader needs to know some general characteristics of the course. On the TU Delft-website the following information is given:

> "The Civil Engineering programme consists of a three-year bachelor part and a two-year master part. The bachelor programme, lays the foundation with subjects such as: maths, mechanics, design methods and construction techniques. You will get acquainted with the three themes: Building, Water and Transport. There are also elective technical and non-technical subjects that provide an introduction to the subjects in the master programme.
>
> After successfully completing your final assignment, you will be awarded the title Bachelor of Science (BSc), a degree which allows you to the master programme, where you can choose one of the following five specialisations: Building Engineering, Structural Engineering, Transportation and Planning, Hydraulic and Geotechnical Engineering and Water Management. The subjects you take will be specifically for your area of specialisation. You will also take a number of elective subjects at or outside of the faculty, possibly even outside TU Delft. Then, of course, there is your internship, which you can arrange in the Netherlands or, maybe abroad.
>
> At the end of the programme you will have earned the title Master of Science (MSc) and you can put the Dutch title, Ir., in front of your name."
>
> (TU Delft, 2007)

In practice, the study setup described above means that the content of the MSc-phase and the ICT usage therein, is highly dependent of the chosen direction. A student who specializes in structural mechanics, uses other tools than a Master student in transportation or hydraulic engineering.

On the other hand, the BSc stage is pretty much the same for most students; in the first two years there are no elective courses, in the third year about half of the courses. This means that for determining a policy on ICT in the curriculum, the BSc-stage is the best starting point.

A general point for attention in the BSc-programme that is not unique to Delft, is the fragmentation of courses: there are many courses but the relationships between courses, dependencies etc. are not well developed.

3.2 *ICT in the current curriculum*

Below a brief overview is given of the main ICT tools used in the current curriculum.

Table 1. Current ICT in the civil engineering curriculum at TU Delft.

1st Year Course	Tool or method
ICT Introduction	
Technical drawing	AutoCAD
Technical computing	Matlab
Modelling of dynamic systems	Powersim
Design project	No specific software is prescribed, but common Office software, AutoCAD and especially Google and Google Earth are extensively used
2nd Year Course	**Tool or method**
Numerical analysis	Matlab
Design project	Office, AutoCAD, Google, Google Earth
Structural mechanics	Maple
3rd Year Course	**Tool or method**
Fluid dynamics	Matlab
Design project	Office, AutoCAD, Google, Google Earth
Structural mechanics	Maple
Elective courses	3D CAD, Matlab, Maple, Together, JBuilder, etc.
Master Phase	**Tool or method**
	CAD, Technical computing software, planning and management software etc, dependent on the chosen direction

3.3 *Weaknesses of the current curriculum*

Looking at the ICT use in the current curriculum, the following observations can be made:

3.3.1 The use of ICT lacks coherency

Many courses use ICT tools but relationships between courses (e.g. use of competences learned in earlier courses) are too often missing. Too often methods and tools are used only once, although there are clear opportunities for follow up.

3.3.2 Programming is not taught

This needs to be explained. Programming is of course only one aspect of ICT, next to information theory, conceptual modelling, software design etc. But according to many, ICT is a technology that one does not understand fully until he has "felt" what it is like to write code. Or: ICT is something you can must (at least partly) learn by doing, thus by encoding. At least at our faculty this is a common opinion.

So for many years, programming was a standard element of the curriculum. After many years of procedural programming methods such as Nassi-Shneiderman diagrams (PSDs) and languages such as Pascal, the faculty switched to object orientation, UML and Java some four years ago. As supporting development tools Together and JBuilder were introduced.

But the new programming course received critical reviews, especially by students who claimed that they would never use the learned competences again. Especially the strong focus on object oriented concepts such as use of multiple classes, class inheritance, encapsulation etc. was often criticized. The common reaction was like "why all this overhead with classes and inheritance structures, I only want to program this calculation method". A switch to another programming language was of course an option to consider, but a logical alternative for Java was not very clear (going back to Pascal did not seem a serious option).

Another weakness of the programming course was its size: for many years programming was part of each year of the study, but over the years this was reduced to only one course in the Bachelors phase, with 4 ECTS (112 hours) study load.

Furthermore, there was a strong need for a Matlab course; Matlab was already used in the second year course Numerical Analysis, but the use of Matlab without previous experience was very difficult for many students. Yet another consideration came from the enquiries on ICT use in civil engineering studies in the US by ASCE, in which was concluded that it is best to either teach programming extensively, or do not teach programming at all (Abudayyeh et al, 2004).

Regarding all the considerations stated above, it was finally decided to replace the modelling and programming course by a combined course of a general introduction into ICT and a Matlab course.

A consequence of this was of course that programming was finally pushed out of the (mandatory part of the) curriculum. Now that consequence was again received with a lot of criticism: many civil engineers, lecturers and students still shared the opinion that a true civil engineer should have programming competences (even if he/she would never use it). Also several lecturers reported that their students lacked programming skills that they needed in the Master phase.

So currently the common opinion is that programming should return into the curriculum.

3.3.3 The use of ICT in the design projects is hardly controlled

Finally it can be observed that the use of ICT in the design projects is hardly controlled. As stated above, 2D AutoCAD, Office software (Word, Excel and PowerPoint) and especially Google and Google Earth are extensively used in the design projects. But the use of these ICT tools is hardly considered as a separate issue in the design courses. So little attention is paid to issues such as how to use AutoCAD, information processing as part of the design process, or methods (and pitfalls) for collecting information on the Internet. So also here improvements seem possible.

3.4 *Towards consistent ICT in the curriculum*

In order to overcome the weaknesses stated above, a proposal is being developed for revision of the curriculum. The main points of this proposal are described below.

3.4.1 Programming

It is proposed that programming returns in the curriculum with a significant position and role. In the first year, an introductory course will be given in which small pieces of

software are developed. The emphasis is on basic concepts and principles (classes, objects, variables, parameters, data types, algorithms). Furthermore the objective is to show the "fun" of programming, by working with small assignments with quick results.

In the second year a more elaborate programming course is given in which more attention is paid to software design and development methods, e.g. information modelling, structured programming, and the use of a software development environment. Also more attention is paid to more complex algorithms for example for solving mathematical calculations (e.g. differential equations).

In the third year the programming work continues in a new scientific computing course, see below.

3.4.2 Scientific computing

An important element of the proposal for revision of the curriculum is the introduction of a new, integrative course on scientific computing. This course will build upon the earlier programming courses but also on mathematical courses, the dynamic systems course, and courses such as structural mechanics and fluid dynamics. In this course elements of all of the mentioned courses come together, thus providing the necessary coherence between courses.

3.4.3 Design, CAD and virtual worlds

Finally, the proposal aims at a more explicit role of ICT in the design projects. Probably the tools that are used will not change very much, although one could think of extension of the set of tools with for example 3D/4D CAD, document management and/or systems for collaborative design. Also Geographic Information Systems could have a much more prominent role. But most of all, awareness of the information and ICT aspect of design processes should be a key point in the design project.

A very recent idea is to transfer the design domain to a virtual world. In other words, it could be very interesting to formulate civil engineering design exercises in a virtual world such as Second Life. One could think of a design course in which students create avatars and are assigned as a team to design and build a structure in a virtual world. This would challenge the students to find a way to organize themselves, to communicate with each other in a structured way, etc., next to the necessary design and building work and the computational work. Recent experiments on collaborative design in Second Life (Rosenman et al, 2006) indicate that this could be a serious option for design education, that can be interesting both from an educational viewpoint and from a research viewpoint. A few months ago, researchers at the faculty of Technology, Policy and Management at TU Delft have acquired virtual land in Second Life and are exploring possibilities to use this land for various educational and research purposes, in collaboration with several other faculties, including ours – so we have a starting point.

3.4.4 Choice of programming paradigm and language

Coherency in ICT in the civil engineering also implies coherency in the choice of programming languages. One may say the choice of language is not a big issue, since all candidate languages offer similar constructs such as if-then-statements, for-loops etc. On the other hand, the experienced controversies around the use of Java indicate that the choice of language does matter.

In discussions on programming languages at civil engineering two main viewpoints can be observed. First, the traditional civil engineers that are experts in mechanics, fluid dynamics etc. see programming basically as a means to solve equations. They put emphasis on calculation algorithms, approximate methods, tolerances etc. They often have a preference for procedural methods, languages and tools (Pascal, Fortran, Matlab, Programme Structure Diagrams). Secondly, there is a community that is more design, process and/or management oriented, and they see programming more as a means to develop tools for design and project management-related tasks. This group is generally more interested in information models, and graphical and geometrical information. They have a preference for object-oriented methods, languages and tools (UML, Java and Building Information Modelling). So the big issue is how to find a compromise between these two approaches.

Looking at possible programming languages, it does not seem very easy to make the right choice; it seems that any choice has its drawbacks. Current candidates that are seriously considered are:

- Python: open source, object-oriented scripting language, probably simple and easy to use, but little used in construction practice;
- Java: see above; could be combined with another software development environment than Together & JBuilder, probably in a way that students are bored as little as possible with the object-oriented "overhead";
- Visual Basic: Microsoft-bound, also simple, but less structured and less stimulating "good programming habits" (Visual Basic .Net is better in this respect, but not much different from Java in the end).

4 EDUCATION SUPPORT

ICT does not only play a role as a tool for the different courses, it also plays a role as general support tool for education. Important issues in this context are the use of the university's blackboard system, the university's policy on laptops for students, and e-learning.

4.1 *Blackboard environment*

Delft University has been using the digital learning platform "Blackboard" since 1999 and it has since been deployed at all faculties. The Blackboard environment is a commercial product and it is widely used at the university. It works generally well, although in some cases the user-friendliness could be improved (some functions work a lot more complicated than should be necessary). It is expected that the system will gradually be improved in the next years; a thorough revision or a completely new system does not seem necessary at the moment.

As a complement the TU of course also has its internet website, which also provides a number of supporting tasks for education, such as general announcements.

4.2 *Student laptops*

A big issue at the moment is the introduction of compulsory laptops for all new students. Rumours have been circulating that new students soon would be forced to buy a "university laptop" for too much money, as a result of a major deal with some laptop supplier. Recently these rumours were denied, etc.

In our view, it is a good idea if all students would have laptops. It is even advisable that they have good quality laptops, since budget systems tend to become outdated quite fast. But in addition, it is very important that the university buildings and infrastructure is fully prepared for the resulting laptop density: there should be wireless internet everywhere, there should be contact points everywhere, there should be sufficient lockers for laptops etc. Regarding the machine itself, it seems highly preferable to use compulsory specifications instead of laptops, and let students buy laptops themselves that meet the specs.

Finally, the role of the laptop in education remains to be seen. The laptops create many opportunities for exciting innovations in courses, but it will probably take a number of years before the study program will fully use these opportunities. In the meantime, many courses will probably remain almost the same.

4.3 *E-learning*

The most prominent role of ICT in education is in the context of e-learning. For example Smit et al (2006) report significant progress in e-learning applied to building and civil engineering education. In Delft, e-learning technologies have been applied with on-line lectures, recorded lectures and with the EuroMasters study ICT in Construction (Beheshti 2007).

Nevertheless, e-learning is still only playing a minor role in the civil engineering study. The main reason for that is probably that face-to-face education is still the standard in Delft; distant learning is not an issue as most students are at the faculty on a daily basis.

5 CONCLUSIONS

This paper reports on a current initiative to develop a more consistent use of ICT in the civil engineering curriculum at Delft University. This initiative is motivated by the vision that the role of ICT in civil engineering practice will only become more important in the future, and especially that ICT will be the key enabler for innovation in construction in the future.

The main findings of this initiative to date are the following:

1. Programming should be either taught extensively, or not at all (Abudayyeh, 2004). Although programming was recently pushed out of the curriculum, it is argued that it should return and even become part of every year of the study. This is motivated by the common opinion at our faculty that civil engineers should at least have some programming experience.
2. Interrelationships between courses is a key priority for curriculum improvement. Subjects taught in one course should be used more often and much more conscious in following courses. For example: CAD in design projects, programming in computational mechanics, etc. A new 3rd year course Scientific Computing is specifically aimed at this priority.
3. Furthermore programming languages, new application areas, student laptops and e-learning opportunities have been investigated and for each subject recommendations are being developed; highlights are reported in this paper.

The findings stated above are in principle specific for our own faculty. But the two main points, (1) teach programming either extensively or not at all and (2) focus on interrelationships between courses, are probably important for many other civil engineering schools as well. On the other hand, in faculties or schools that have a less broad orientation and are more focused on for example building technology or construction management, these issues might play a smaller role. For faculties or schools of Architecture, our findings are probably less relevant, since such schools are much more design-oriented than engineering-oriented. That would mean that the emphasis is much more on the relationship between (creative) design processes and ICT.

Revision of the current curriculum at Civil Engineering in Delft using the ideas and conclusions reported in this paper would help to make Civil Engineering an innovative, future-oriented study that produces skilled and innovation-minded engineers that are better prepared for the future ICT dominated and knowledge-intensive construction industry.

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REFERENCES

Abudayyeh O, H. Cai, S.J. Fenves, K. Law, R. O'Neill, W. Rasdorf, "Assessment of the Computing Component of Civil Engineering Education", in: Journal of Computing in Civil Engineering, ASCE, July 2004.

Beheshti, R., S. Özsariyildiz, S, van Nederveen and E. Dado, "Effects of Teaching Environments and the Digital Media: The Case of a Parametric Design Course", in D. Rebolj (ed), Proceedings CIB W78 Maribor 2007.

ECTP (European Construction Technology Platform), Focus Area Processes and ICT, "Compiled RTD ideas for: ICT-supported new integrated processes for the construction sector", 2006, available for ECTP members at http://www.ectp.org.

IAI International Alliance for Interoperability website: http://www.iai-international.org.

Kam C, Fischer M, Hänninen R, Karjalainen A and Laitinen J (2003) The product model and Fourth Dimension project, ITcon Vol. 8, Special Issue IFC - Product models for the AEC arena, pg. 137-166, http://www.itcon.org/2003/12.

Manubuild, EU project website: www.manubuild.org.

Oosterhuis, K, architectural office website: http://www.oosterhuis.nl.

Rosenman, M., K. Merrick, M.L. Maher and D. Marchant, "DesignWorld: A multidisciplinary collaborative design environment using agents in a virtual world", in: J. Gero (ed), Design Computing and Cognition '06, Springer.

Smit, D., J. Wall, C. Taylor and M. Betts, "eLearning modules – increasing knowledge of collaboration tools for construction management", in Proceedings Clients Driving Innovation: Moving Ideas into Practice, CRC for Construction Innovation, Australia, 2006.

TU Delft, Faculty of Civil Engineering and Geosciences website: http://www.citg.tudelft.nl.

All websites have been accessed in March 2007.