Implementing Information Technology in Teaching: A Case Study

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INTRODUCTION

Information Technology (IT) is not only affecting the way we design, construct and manage buildings, it also impacts the way architecture is taught. What used to be a marginal influence on teaching has become a focus of experimentation at many architecture schools. Educators that wish to integrate IT into their teaching, lack guidelines and information on precedents in order to conceptualize a digital resource that best meets their specific needs. This paper discusses the design, implementation and evaluation of the *Interactive Structures Modules* (ISM, see Fig.1), a digital teaching tool for teaching Structures to architecture students. The tool accompanies an instructor-taught course at the Harvard Graduate School of Design (GSD).

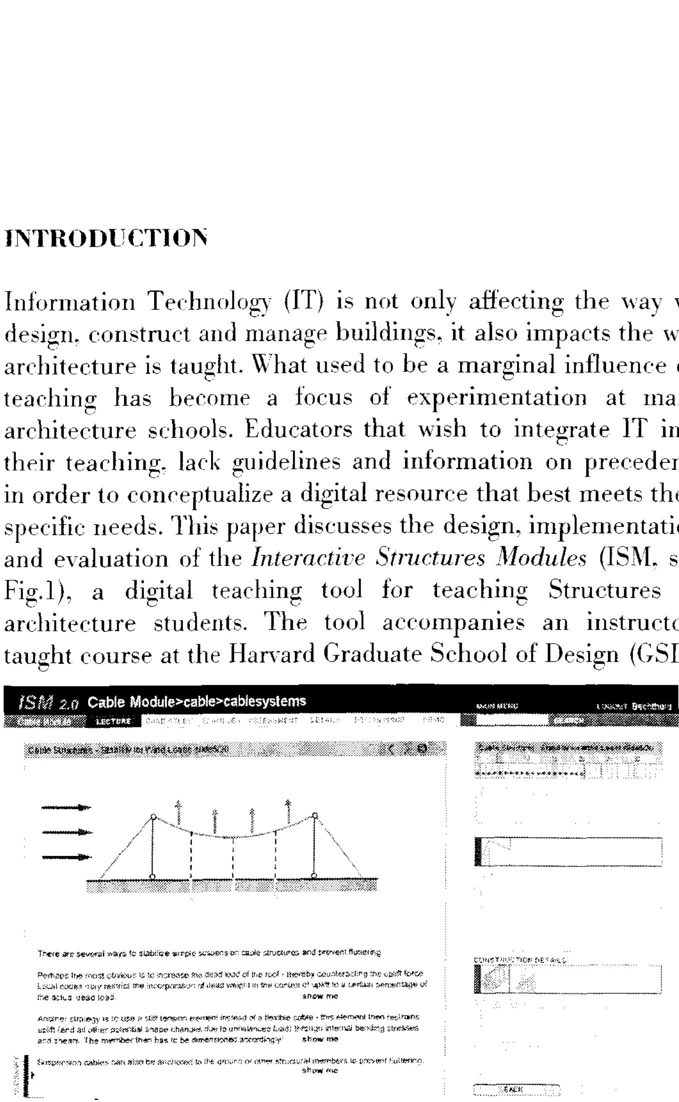

Fig. 1. ISM interface on cable structures.

Teaching Structures to architecture students means accommodating a group of students with a wide range of capabilities in quantitative analysis and in the design of structural systems. A significant percentage of students seek an architectural education as a way to enable creative expression and have little interest in the analysis and design of structural systems. Students at the GSD traditionally perceive the Structures course as difficult and fast-paced. The two-semester course is embedded in a sequence of technology courses that cover Building Technology as well as Environmental Systems. During the 3 1/2 year-long MArch I program, Structures is taught in the 3rd and 4th semesters; the class size ranges from 45 to 60 students.

GSD students spend the majority of their time on Design Studio, and support courses such as Structures have to compete for their attention. Due to the amount of material to be covered in Structures the course dealt little with design applications of structural principles. The synthesis between design and structures was to occur in design studio, but students needed more help on dealing with issues of structure than could be provided in the studio setting. The author decided to change the nature of the Structures course and introduce a more in-depth study of structural system design. By doing so the expectation was to improve the motivation of students and teach the material more effectively. The shift in the course focus depended on an acceleration of the learning pace since all fundamental topics still needed to be covered. By providing an online resource the instructor hoped to accomplish this goal.

PEDAGOGIES AND PRECEDENTS

Prior to developing an IT-enhanced course it is essential to clearly define the pedagogical objectives. This section presents a brief literature review and precedent study that helped to conceptualize key aspects of ISM. Two pedagogical theories were particularly relevant.

Perkins *Theory One* proposes four basic elements for successful teaching: during the first phase, clear information needs to be delivered to the student, and progress of a student should be monitored. Students should then engage in thoughtful practice of the material, immediately followed by feedback from the instructor. During the last phase of learning the student engages in highly rewarding, motivating activities with the objective to obtain a deep understanding.

Theory One also refers to what Perkins calls the "Pedagogy of Understanding" (Perkins 1995), an approach adopted as a key pedagogical concept for distance learning (Perkins et al 1995). *Teaching for understanding* emphasizes the need to present the general subject area – the *generative topic* - in an engaging way through multiple resources and formats. It is here that the use of IT appears to be an advantage since visualizing abstract concepts through interactive multimedia presentations can deepen student's understanding. Within these broad areas, for example 'beams', instructors need to define more focused areas or *understanding goals* such as 'stresses' or 'deflections'. Students actively understand these goals by means of *understanding performances* designed ". . . to help students develop and demonstrate understanding" (Wiske 1995). In Structures *understanding performances* can include the study of cases, design assignments or certain types of problem sets. Assessment and feedback should be ongoing during this learning process.

While developing ISM the author was able to draw from extensive experience with IT-supported teaching methods at the GSD. My predecessor, Professor Spiro Pollalis implemented a web-enhanced Structures course in the spring of 1998. He subdivided the course material into weekly content modules and posted all course material online. An asynchronous discussion forum complemented the course web site. With all materials constantly at their disposal students were able to study at their own pace and adapt to the varying time demands for studio. The pedagogical concept, developed in collaboration with researchers of the Harvard Graduate School of Education, was based on the phases of preparation, information from sources, thoughtful practice, feedback and reflection. Pollalis describes his approach as ". . . automating the cow path" (Pollalis et al 2000). The use of IT enhanced the efficiency of presenting the subject matter without changing the course content.

INTERACTIVE STRUCTURES MODULES: OBJECTIVES AND DESIGN CONCEPTS

Understanding user profiles and needs is key when designing an online teaching tool. For the Structures course at the GSD it was clear that helping weaker students to study more efficiently would enable the whole group to move along at an increased pace. For weaker students, the lack of basic mathematical and physical background knowledge frequently aggravates their difficulties in Structures. Other students do not perform well because they lack the motivation to engage the material. By cross-referencing structural concepts to design and building construction it was hoped to better motivate these students. At the same time certain students are particularly interested in Structures and need more challenging material. A small group waives the first semester of Structures but participates in the second semester. These students have to review key concepts quickly in order to ease their integration into the class.

An online teaching environment was created that met these diverse needs. Its main principles were a *customized learning experience* that responded to individual needs, *interactivity* and *frequent self-assessment* during the learning process. Engaging students through active involvement in *understanding performances* was meant to increase interest in the topic and improve learning. In addition the instructor wanted to be able to easily manage and edit the content.

Information Categories: Information in ISM is categorized in 'Content Modules' and 'Content Format'. The 'Content Modules' include the different *generative topics* of Structures, for example 'trusses' or 'frames'. The information within each 'Content Module' is presented in the following 'Content Formats':

Lecture: presents a subtopic or *understanding* goal within a content module (e.g. 'buckling of long columns' for a content module on 'columns')

Case Study: explores issues of Structures within the context of a real building; case studies are often associated with several content modules, emphasizing the connections between topics

Example Problem: interactive example with solution
Assessment: qualitative and quantitative questions that allow students to assess their comprehension of the material; includes graded quizzes

Construction Issue: ties in a structural topic with questions of building construction and detailing

Design Issue: highlights the design implications of a structural topic

Database: The content of ISM is presented in small content units that resemble electronic *Learning Objects* (Wiley 2001). These are stored and organized in a relational database. Frequently, topics – as for example 'reactions' – are dealt with explicitly in one content module, but relate to many different subsequent topics. The database establishes and controls these associations. Links in the interface point out connections between content or to the broader architectural context. By providing a rich learning environment it was hoped to improve student's motivation to think and to understand the material. These dynamic associations of content also expose advanced users to the more challenging complexity that corresponds to their interests.

Interactivity: Users can expect interactive feedback on three different levels. Mostly qualitative questions that encourage users to actively engage the material establish the first level of interactivity. The answers are automatically evaluated and responses are displayed instantly. This feedback mechanism is interspersed in lectures, example problems and case studies; it allows a quick self-assessment on how well the material has been understood. Users that are merely browsing the site without actively studying can choose to simply display the answer – ISM does not insist on questions being answered!

Mostly quantitative self-assessment questions in the content format 'assessment' constitute the second level of interactivity. These *understanding performances* are designed to test whether the content of a complete module has been understood and can be applied. Users submit their answers from a pre-selected range of solutions and receive immediate feedback.

The third level of interactivity is the graded quiz. Each registered user can only login once for a given quiz, and the results are recorded in the database. On submitting the quiz, the grade, and the correct answers with detailed explanations are displayed instantly - making students immediately aware of any shortcomings in their comprehension of a topic.

Another interactive feature is the searchable glossary of technical terms that students can access at any time. Each content frame in the database is associated with its related technical terms. Users access these pre-selected terms from within the content file, or alternatively search the complete database of glossary terms.

Customized User Experience: In order to provide a customized learning experience, all content is categorized into 'Basic', 'Advanced', 'Supplementary', and 'Nutshell'. 'Basic' content contains unabridged material that is essential for a topic, while 'Advanced' material builds upon the understanding of the fundamentals and deals with more complex issues. Design related questions or issues of building construction are generally classified as 'Supplementary'. 'Nutshell' content provides a brief summary of a topic, highlighting key issues that are necessary for a basic understanding. It is geared to students who wish to review selected concepts quickly.

A further degree of customization is added by allowing users to study a topic at their individually desired depth. Weaker students may wish to display detailed explanations that would bore and de-motivate stronger students. Options such as 'more explanation' or 'more detail' are thus widely used throughout ISM. Links to explanations on underlying mathematical and physical principles address the needs of students with weaker backgrounds in those areas.

Interface: The navigation features of the interface are largely image based as opposed to text based, thus taking the visually oriented nature of a design education into account. Associated content files are displayed graphically with thumbnails and mouse-over text.

The interface of ISM accommodates two different modes of access – referred to as 'lecture mode' and 'browse mode'. Both modes display the same data, but differ in the amount of guidance that users receive when advancing through the material. *Lecture mode* presents users with a pre-defined, linear path through a content module. The large graphic display area on the left presents the current file, starting with a lecture at the beginning of a module (Fig. 2). While advancing through the lecture ISM displays recommended examples, case studies or self-assessment questions in the area to the upper right. The links to supplementary information such as construction detailing and design issues are displayed below in the form of smaller thumbnail images. These related links are designed for students who wish to gain a deeper understanding of the material. Recommendations and supplementary links are programmed on a frame-to frame basis.

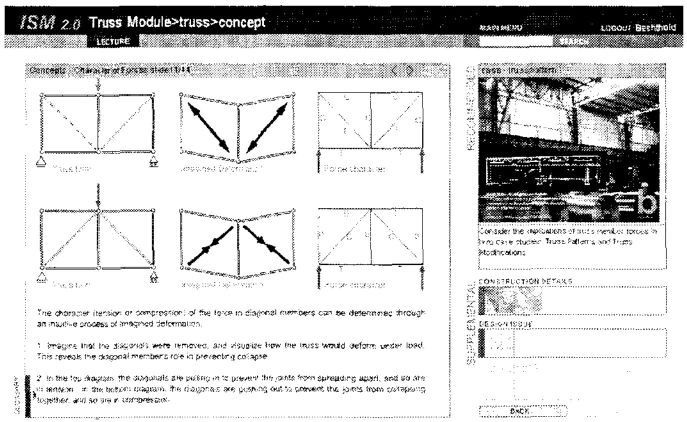

Fig. 2. The 'lecture mode' interface in the truss module: basic principles of trusses are explained in the large area on the left. The 'Recommendation' on the upper right points to a case study, the links below to related construction details and design implications.

In *browse mode*, users are free to access the content in any order they desire. All data is still organized according to content modules, and the associated links are displayed as thumbnail images with explanatory text (Fig. 3). Browse mode establishes no hierarchy between related information. This mode is geared towards users that wish to find information on a certain topic. A site-wide keyword search is accessible in both modes, allowing users to quickly retrieve specific content files, which then are displayed in browse mode.

In order to enable multimedia content with relatively low bandwidth – students can log on from their homes rather than from the school's Local Area Network – the vector-based Flash file format was chosen as the standard for the site. It enables scripting through an associated programming language and can be dynamically driven by a database. The free plug-in player works on common browsers and is independent of individual operating systems. A zoom function allows users to enlarge selected portions. From the instructor's perspective this file format facilitates the frequent editing of individual files for content updates.

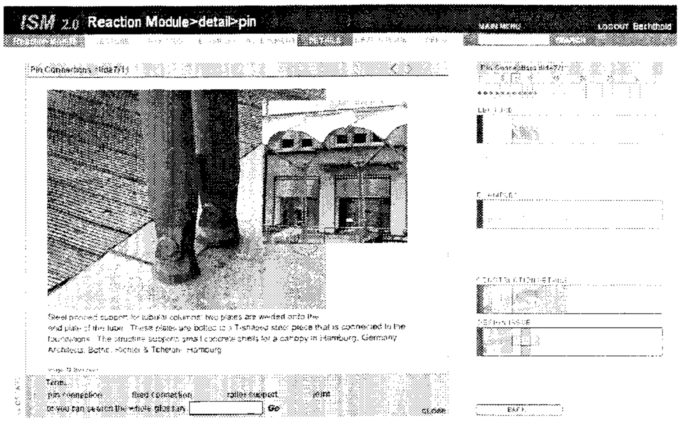

Fig. 3. The 'browse mode' interface contains the main content display on the left, with thumbnails on the right pointing to related content in the module. The glossary is located in the bar at the bottom of the screen.

IMPLEMENTATION AND USER FEEDBACK

ISM was developed over the summer of 2001. During the regular lecture course taught by the author three content modules were successively implemented in the following two semesters. Once individual content modules were released, questionnaires were distributed to the users and the feedback incorporated in the release of the next module. The course met for two required weekly class meetings and offered two optional weekly lab sessions. A weekly quiz was administered in class and replaced the mid-term exam. All course material such as lecture handouts, weekly group problem sets, handouts, example problems and quiz solutions were posted on a separate course web site.

Module 1: Equilibrium

The first content module on 'Equilibrium' covered fundamental concepts of structural analysis and served as a pilot study to test basic functionalities. This module was released in the third week of the fall semester of 2001 to a class of 54 MArch I students. Compared to later releases the content was less interactive and did not include a graded quiz. The interface was similar to the current *browse mode*; *lecture mode* was not available.

Prior to releasing the ISM module on 'Equilibrium' the instructor lectured on the same topic. Students were asked to study the material online using ISM, solve the group homework problem, and submit a detailed questionnaire on ISM. At the end of the weekly module the quiz was held as usual in class. The questionnaire was designed to track user behavior by asking students to measure the time they spent on individual 'content formats' ('lecture', 'example problem', etc.). Students were also asked to evaluate content and interface, attribute values for their learning of the material, and suggest future use of ISM at the GSD.

Student's responses were generally positive, and 32 students out of 54 returned the questionnaire. The interface was criticized for not being sufficiently user-friendly, and students experienced technical problems related to incompatibilities with a particular operating system. Many students requested a more hierarchical organization of the material in order to facilitate their choices. The attributed value of ISM for the learning of structures averaged 3.65 (standard deviation 0.96) on a scale from 1 (low) to 5 (high), and the quality of the interface was rated 3.37 (standard deviation 0.73) on the same scale. Students spent an average of 53 minutes on ISM, with most time spent on 'lecture' and 'example problems'.

Module 2: Trusses

In response to students' comments the more guided 'lecture mode'-interface was added to the site. When the content module on trusses was released in December of the same semester, it also included a graded quiz and a high degree of interactive features. Following the lecture the author asked students to study the material online and then do the graded online quiz within 4 days as an individual assignment. A second questionnaire was distributed and evaluated. Again 32 students from a class of 54 returned the questionnaire, 12 of these students had not returned a questionnaire after the first module. Two newly added questions inquired whether students felt the interface had improved, and whether students preferred using *lecture mode* or *browse mode*. 87.5 % of all responding students preferred the revised interface to the previous version, and 75% of responding students used 'lecture mode' instead of browse mode.

The interface quality was now rated slightly better at 3.48 (standard deviation 1.04) on the 1 – 5 scale. Some students had still experienced technical difficulties while accessing ISM, which gave rise to frustration and general skepticism towards the technology. User behavior – the amount of time spent on individual 'content formats' – was very similar to what had been reported in the first module. The average time spent on ISM increased to almost 2 hours – a phenomenon partly attributed to the required online quiz that took students, on average, 36 minutes to complete. Students rated the quality of the content and its value for their learning slightly higher than in the first module (Fig 4).

The attributed value of ISM for the learning of Structures increased to an average of 3.74 (standard deviation 0.69). Only for the category 'glossary' was the quality judged to be much higher than the learning value – indicating that most students were familiar with the terms used and did not consider the glossary essential for their purposes.

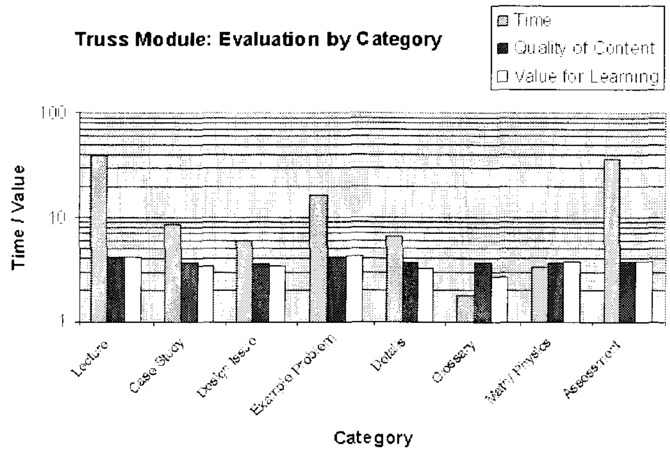

Fig. 4. Time students spent on individual content formats (lecture, case study etc.), quality rating and the attributed value for their learning on a logarithmic vertical scale: Lecture and self-assessment were the most frequented categories, followed by example problems and the case studies.

Module 3: Cable Structures

The third module treated 'Cable Structures' and was released to the same class with all previous and six new students in February 2002. The user interface remained graphically unchanged, but compatibility problems with specific browser versions and operating system had been resolved. The lecture material was now narrated, addressing earlier comments on the difficulty of extensive reading on computer display. Following the lecture students were again asked to study the material in ISM, submit the online quiz and fill out the questionnaire. 31 students from a class of 60 returned the questionnaire. The quality of the interface was now rated significantly higher at 3.79 (standard deviation 0.70), an effect that can be attributed to the more stable technology. The average value for their learning remained constant at 3.75. Users now spent even more time studying in ISM, averaging 2 hours and 15 minutes, with the graded quiz taking an average of 32 minutes to complete. Figure 5 summarizes the survey results from the first three modules.

		Module 1 Reactions	Module 2 Truss	Module 3 Cable
User Behavior				
Average Time Spent in Minutes		53	117	135
Weak students spend longer, strong students shorter time		yes	yes	yes
Value for learning similar for weak and strong students		yes	yes	yes
Attributed Average Learning decreases for stronger students		yes	yes	yes
Suggested Future Use				
Summer Online Course		9	5	3
Semester Online Course		2	2	3
More Design Oriented Course		5	8	5
Replace Course Web Site		7	9	3
Supplement Course Web Site		13	12	14
Value for Learning, Ranking	1	Lecture	Example	Example
	2	Example	Lecture	Assessment
	3	Math/Physics + Assessment	Math/Physics	Lecture
	4	Design Issue	Assessment	Math/Physics
	5	Glossary	Design	Case Study
	6	Detail	Case Study	Detail
	7	Case Study	Detail	Design
	8		Glossary	Glossary
Average Value for Learning 1-5		3.652	3.745	3.75
Interface Quality 1 = poor and 5 = very good		3.37	3.48	3.79

Fig. 5. Summary of user feedback.

EVALUATION

A primary objective for developing ISM was to enable a customized user experience and improve learning. The author related the questionnaire responses to the final ranking of students at the end of the semester in order to understand how different students use and evaluate ISM. It was not surprising to find that lower ranking students spent on average 15 – 30% more time studying in individual content formats (Fig. 6). This tendency was less pronounced for the categories 'construction detail' and 'design', indicating that these supplemental topics also attracted stronger students.

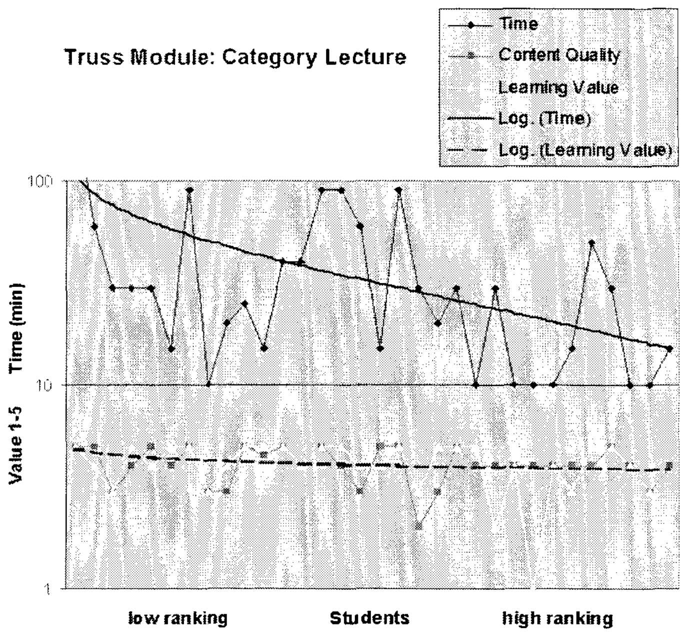

Fig. 6. Time spent on the truss lectures (upper portion of the diagrams), evaluation of content quality and learning value in the lower half (scale 1-5), ranked by final grade, with lowest ranking student on the left and the highest ranking student on the right.

These students generally considered the value of ISM for their learning to be slightly lower than weaker students (Fig. 7). The difference was small but consistent throughout content modules and formats. This indicates that the customized content in ISM appealed to a wide variety of students, with weaker students profiting slightly more than stronger students.

Students increased their rating of both content and interface with the release of each module. While this effect may be partially attributed to a growing familiarity with the interface, a correlation with the increasing interactivity of ISM is also likely. Students spent more time on ISM as the quality and the interactivity of the environment improved.

The categories 'lecture', 'example problem', 'assessment' and 'math/physics' are consistently rated as the four most useful content categories. This selection shows a preference for well-guided and structured information.

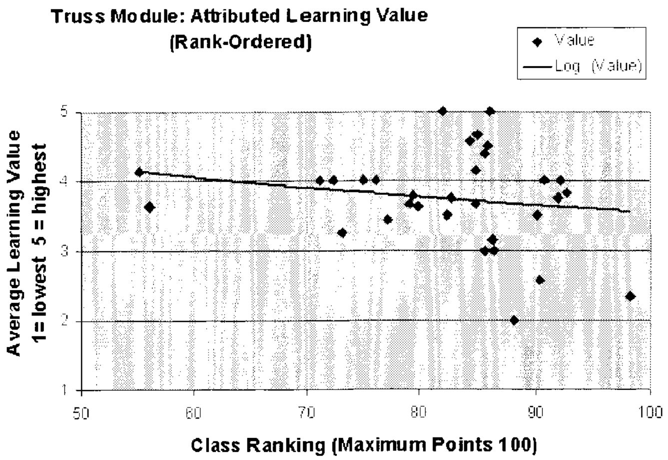

Fig. 7. Average attributed learning value of the truss module in relation to final student ranking in the class: lowest ranking student on the left, highest ranking student on the right.

A shift in feedback was recorded in what students perceived the best future use of ISM in the Structures sequence at the GSD (Fig. 8). Students were asked to choose one of the following options:

1. Provide students an opportunity to study during the summer and then waive Structures.
2. Replace the current course completely with a virtual course that uses ISM during the semester.
3. Let students prepare for Structures during the summer and then concentrate more on design-oriented applications in the course.
4. Replace the current lecture information on the course web site but keep the course format as it is.
5. Supplement the current course web information and keep the course as it is.
6. Not at all.

Between 55 and 61% of respondents suggested to keep the existing course unchanged and use ISM to enhance the resources available to them. The number of students wanting to use ISM to study during the summer and then waive structures decreased from 25% after the first module to 10% after the third module. This indicates that students, after having been exposed to the topic area for some time, were more motivated to study Structures. They also valued the personal interaction with instructors and teaching assistants.

The latter interpretation is consistent with students' most frequently noted disadvantage of online learning environments, the lack of personal interaction (McGorry 2002). While students appreciated the ability to study material at their own pace, review difficult concepts as often as they wished and have a broad range of related topics presented to them, they repeatedly pointed to the value of personal interaction.

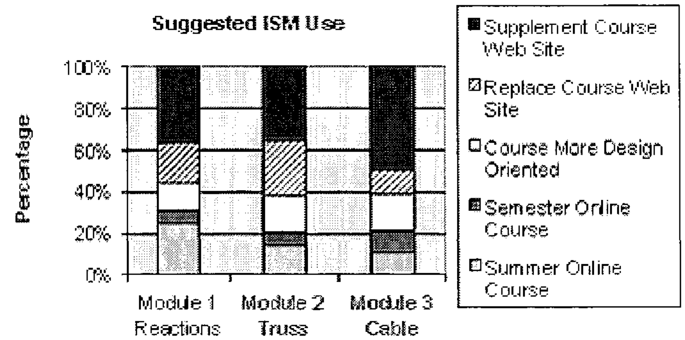

Fig. 8. Most students preferred to leave the course as it is and use ISM as an additional resource.

CURRENT ISM USE AND CONCLUSION

The current release of ISM covers all topics that the instructor is teaching in the first semester of the Structures sequence. The desired change in the course content is currently being implemented: the instructor conducts a two- to three-week long structural design workshop at the end of each semester, providing for a motivating *understanding performance*. The in-class quiz is partially replaced by quizzes within ISM. Students' response to doing a quiz online instead of in class has been enthusiastic, with 60% of students preferring an online quiz to the in-class quiz, and 20 % being undecided. Online quizzes and referring weaker students to additional help within ISM has freed up time to include extensive structural design projects. This has in turn improved motivation, and ultimately made learning and teaching Structures more enjoyable.

Monitoring user behavior and evaluating user feedback is an important aspect when developing online learning environments. Technical problems must be addressed as soon as they appear, because they tend to inflict a negative attitude to IT-supported teaching. An incremental approach to design and implementation of digital teaching tools enables user feedback to inform the ongoing design process. The analysis of feedback contributes to shaping a learning environment that meets the pedagogical objectives. The additional time needed for students to familiarize themselves with an online learning environment and provide constructive feedback needs to be taken into account when developing the class schedule. Tracking user feedback in a rank-ordered manner shows characteristic patterns of access for weaker and stronger students. When designing a teaching tool that addresses diverse user groups this information is essential.

In the case of ISM, most of the project objectives were met. Students' reactions to ISM are extremely positive. Being able to access customized support has improved the overall motivation of the class. A side effect has been that an increasing number of students are consulting the GSD's Structures teachers for their studio projects.

ISM is currently being evaluated for adoption as an online teaching environment for a real estate course at the GSD. The database and interface design allow for a simple conversion for other types of content. In conclusion we have seen that interactive online teaching tools can support graduate education in architecture if they allow a customized learning experience, address the broad context and allow for frequent self-assessment of the learning process.

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