Learning by Seeing: The TEMAS Multimedia Learning Objects for Civil Engineers

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Seeing is Remembering

A goal of engineering and architecture bachelor and master's programs is to provide students with practical and technical preparation in the mechanical characterization of materials and structures: future architects and civil engineers should be able to recognize and describe different construction materials and their behavior when used for building particular types of structures in relation with stability and safety.

Effective teaching for this topic requires not only theory—physical laws that describe the behavior of structures and materials (e.g., steel or concrete, beams or slabs)—but also direct experience, in order to see the effects of forces and to observe the different tests required for certification (Wagenaar, et al., 2004). This represents a challenge for at least three reasons:

Facilities: Only a few universities have a properly equipped laboratory for the execution of experimental tests for and with the students. Such tests, which can involve the failure of a concrete slab, require a large space and special devices.

Cost: Tests are expensive due to the necessary involvement of qualified lab technicians and the use of costly materials. For example, a bending test on a 9 meters long (29.53 feet) reinforced concrete beam costs about 15'000 CHF/15,000 US$, and such cost can go up to 50'000 CHF/50,000 US$ for other tests (CHF = Swiss francs).

Time: Laboratory activities are usually given reduced time within the curriculum, and some tests require a long time, e.g., for simulating the structural forces in a steel structure.

Project context

TEMAS (experimental TEchniques on MAterials and Structures) developed an online multimedia support in order to tackle these issues. The goal is to allow students to see—not only to read about—materials and structures in order to generate an experience that can pinpoint the acquisition of particular and applicative concepts.

TEMAS (*www.e-temas.ch*) is a project founded by the Swiss Virtual Campus, a federal program for higher education (SVC, n.d.), and run from end 2005 to mid 2008. The partners of the project are the Department of Environment, Constructions and Design at the University of Applied Sciences of Southern Switzerland, the University of Applied Sciences of Western Switzerland, and the Accademia di Architettura at the University of Lugano. The global cost was about 400'000 CHF (150'000 CHF financed by SVC, the rest invested by the partners; 1 CHF is about 1 US$).

The core idea

All project partners have a well-established teaching tradition in structures and materials, and all have special lab facilities, different from each other's, in which some costly tests and experiments are run every year to the benefit of a single class, that is 10-30 students—and then it is gone. The basic idea is that such tests can be videotaped, digitized, edited, enriched with additional information and stored as learning objects (LO). Digital technology within TEMAS is a means for making experiences reusable and not wasting resources.

TEMAS wants to achieve some important goals:

- Tackle the issues presented above, providing teachers with rich multimedia learning resources that can integrate the limited (as facilities, costs, and time) lab experiences available at their home institutions.
- Support the development of outreach programs, providing institutions with online materials, e.g., continuing education cycles parallel to the profession.
- Provide students with more flexibility, as online LOs can be accessed and used from different places.

The instructional product

The main approach of TEMAS is providing tools for case-based teaching and learning, reinforcing direct experience, and enhancing learning by seeing. TEMAS is focused around three main learning goals:

- Understanding the basic concepts (properties, physical laws, dynamics) of mechanical characterization of materials and structures , as a part of Structural Mechanics and Static. This is addressed with multimedia presentations of the theory behind experiments, promoting case-based learning.

- Becoming familiar with the procedures and tools used to perform structural tests. This is addressed by allowing students to see these tests through pictures, text, and audiovisual materials.
- Managing references and understanding the Swiss and European standards concerning structural tests. This is addressed by connecting the norms with the experiments and tests available as LOs, and creating meaningful connections among related LOs.

TEMAS offers a rich multimedia support for deep understanding through seeing experiments that are rarely and often only partially replicated in a lab. This happens mainly through videos, which are packed within a more extended framework that presents three types of useful materials: a) Theory sheets that highlight and explain the physical rules behind the tests, b) References to national and international legal norms about structural tests, and c) A self-test.

The LOs developed within TEMAS therefore bring together the different facets of structural tests, namely the practice of experiments, theory, and legal aspects. This leads to significant savings for the schools, and enhances the experience of students who will be able to directly relate three aspects that are often assigned to different classes.

Video

The TEMAS approach capitalizes on the few tests carried out every year at partner universities to make that experience reusable for other students. The first step was therefore to videotape such tests (see Figure 1). However, some of these tests, especially compression tests, which are different from shock tests, span over eight or more hours; also, some important details are very small, and cannot be properly observed on a screen. Adding a simple editing step to videotapes can overcome these problems and enhance student experience; videos can in fact add short comments about what is being presented, or visual cues. Videos were digitized and edited in two ways:

Figure 1. A video within a TEMAS LO

1. Except for shock tests, which happen in a few seconds and are presented at normal speed, the final video clips have an average length of 5-10 minutes, and include "fast forward" sections in which time is accelerated (e.g., during the compression on a concrete pillar the diffusion of cracks in the structural element can take hours). While this creates a gap between the actual test and the instructional presentation, it also allows students to focus on key events and create a synthetic and accurate mental model of the process.

2. During live experiments, the instructor points to important details and provides comments about the physics that regulate the process. In TEMAS videos, scarcely visible or even invisible details are highlighted in order to direct students' attention (see Figure 2). These include the progressive growth in length of cracks in concrete beams during bending, the extension of tensors, or the representation of the forces in action.

All videos have audio comments. Also, a snapshot version of the video

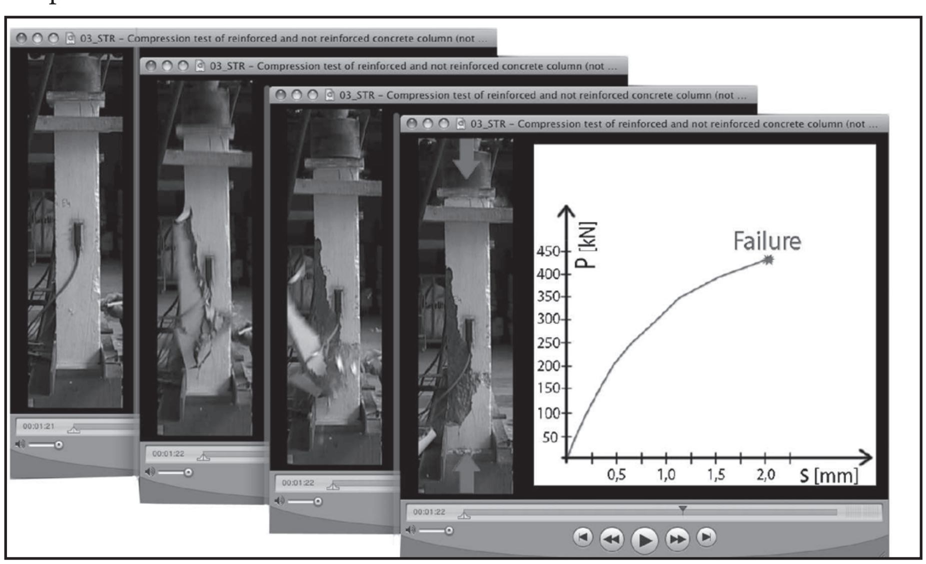

Figure 2: Video with editing enhancements

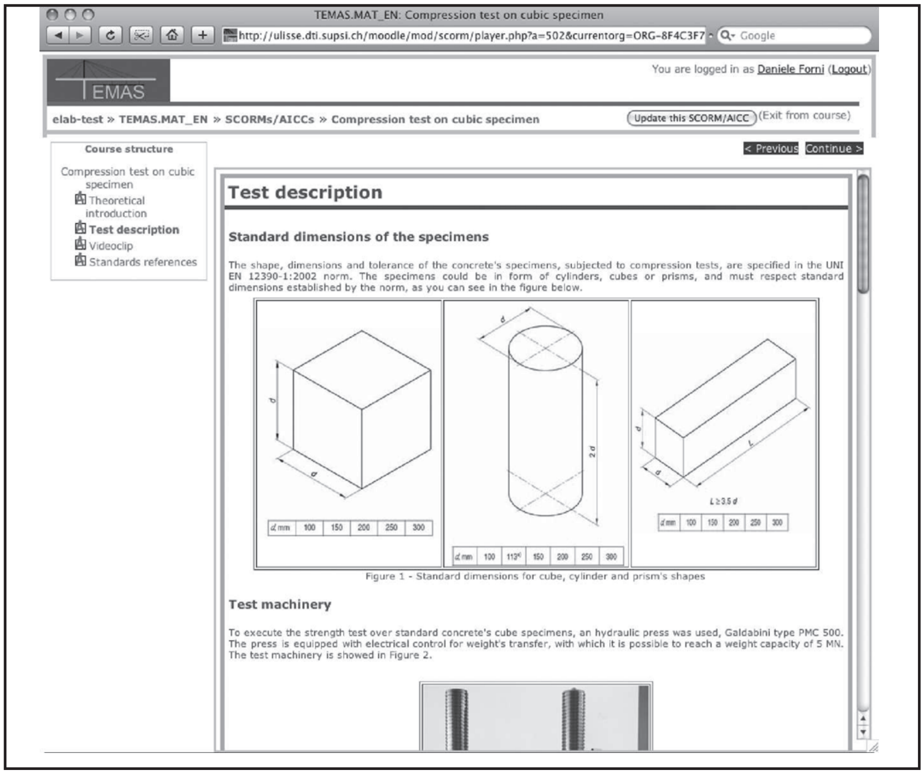

Figure 3: A theory sheet

with textual comments is available in case of network or software problems.

Theory sheets

In order to let students correctly understand the physical processes at work, each LO includes a section that presents accurate explanations through text, formulas and diagrams (see Figure 3). This is indeed what students would find in a standard book, but it acquires here a completely different meaning: text and diagrams become the formal description of a process that students have seen in a particular instance—students are prompted to ask the right questions and to generate a more accurate insight (Botturi, 2004; Lonergan, 1990). This is radically different from the situation in which students go through a text that describes a generic test of which they have to create a mental image without direct experience. In this latter case, text and pictures do not explain an experience, but become surrogate. Also, accompanying explanations to the video provide students with a repetition of the same content (the test) from different perspectives and with different languages, supporting dual encoding (Clark, 1999).

Theory sheets describe the experiment or test and the principles behind it through text and pictures, graphs and other images, using Flash animations for visualization.

References to Standards

In addition to the video and the explanatory text, references are provided to the Swiss, European and international standards (see Figure 4). In this way students can learn the basic norms that will regulate their future profession not as a separate thing from the "nuts and bolts" of structural analysis, but as the natural context in which such tests originated. This is a key step in order to identify legally mandatory items and constraints for each test, not from the physical but from the normative point of view. Unfortunately, due to strict copyright regulations applied to the full text of regulations, it was not possible to include the full text into the instructional materials.

Self-tests

Each LO provides the students with an opportunity to control their level of understanding with a self-correcting quiz. While extending the possibilities for autonomous learning, this can be also used by teachers to track the level of understanding of the whole class.

Multiple-choice questions have been developed in a stand-alone format, e.g. with JavaScript, or Flash, or with free tools like Hot Potatoes.

Language and production

In order to make content reusable for a larger audience, all content is written in English and Italian. References include standards from different countries. By comparing standards of different countries, students can also

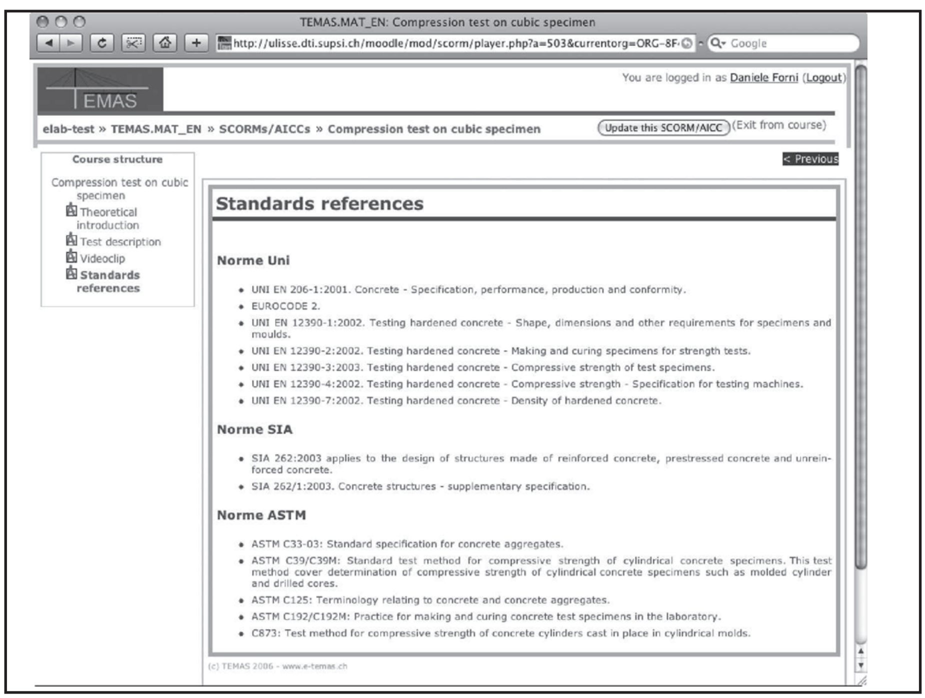

Figure 4: Normative references

appreciate similarities and differences at an international level.

It is important to notice that the "serial production" of instructional materials on different tests sharing the same structure and interface contributes to another goal of the instruction: identifying similarities and differences between them, e.g., variations in applying the same compression forces on different materials, or different forces on the same material.

Packaging and distribution: LOs for reusability and interoperability

All the contents for each test were produced using common web formats, and then packaged as LOs with the goal of maximizing interoperability and reusability (Cantoni & Botturi, 2005; Wiley, 2000).

All media were embedded in web pages, with the video clips converted to Flash Video, which only requires a simple plug-in, usually already installed on most computers at partner schools. A skin was selected that allows students to pause, fast forward and rewind the clip, therefore enhancing usability and flexible use.

Finally, instructional materials were packaged as individual LOs following the SCORM (n.d.) standard (see Figure 5). In this way a) they are structured in a sequential navigation pattern, and b) can be easily imported in most Learning Management Systems, taking advantage of user tracking functions to monitor the actual use of students.

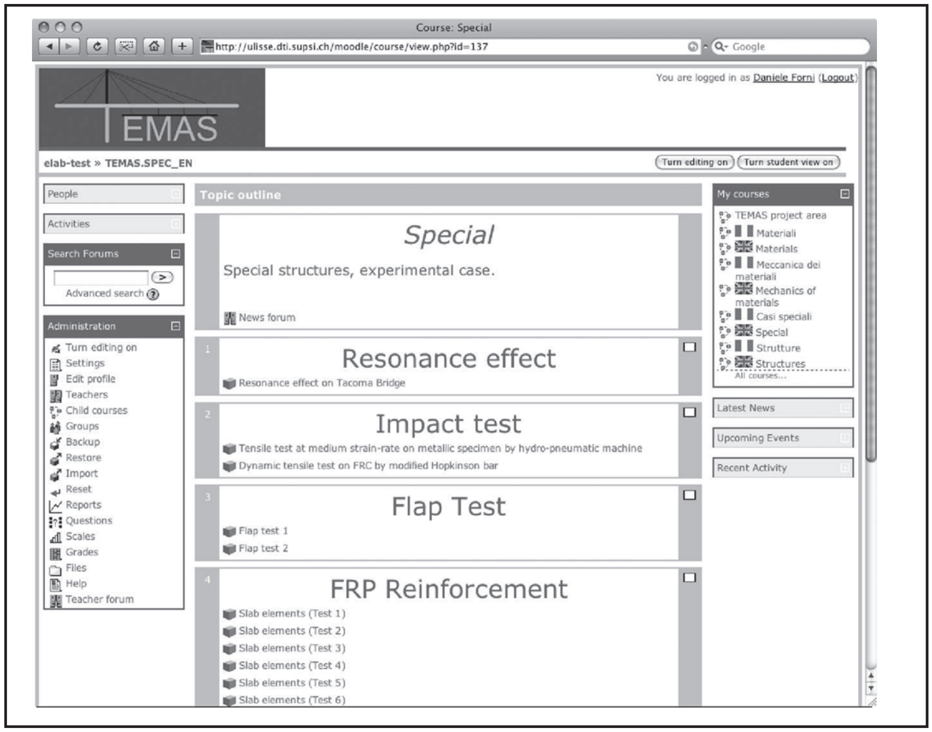

Figure 6: The Moodle-based TEMAS repository

Repository

The TEMAS project provided a chance to start production of a set of 90 LOs, supporting a total of 120 hours of study. LOs were then collected into an online repository powered with Moodle (see Figure 6).

Indeed, the repository is potentially work in progress, which can be enriched with the experiences realized in the laboratories of Swiss and international universities over the years. Actually, the project team asks all laboratories to enrich the repository base by sharing videos of the experiments run in their own facilities.

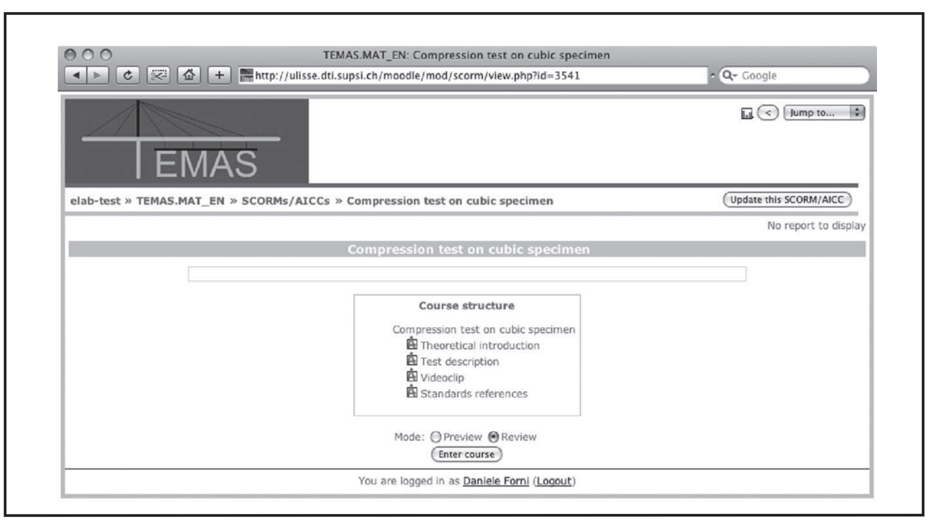

Figure 5: The entry page of a TEMAS SCORM LO in Moodle

LOs are grouped by topics (e.g., concrete, steel, etc.) and indexed with keywords for quick retrieval. Topics are: Mechanics of materials (stress, strain, constitutive law, axial loads, bending, torsion, shear, etc.), Materials (fresh concrete, hardened concrete, cement, mortar, steel, plastic, FRP, etc.), Structures (column, beam, wall, slab, etc.), and Special Cases (dynamic tests, structural test, blast, earthquake, etc.).

The updatable database represents a large scale economy for the university partners in the project. Other experimental tests developed in research or field projects could easily be included in the database.

Learning by Seeing: Integration in the curriculum

The main goal of TEMAS instructional materials was allowing students to see and understand specific static tests of which they would otherwise only read in books.

Currently, about 90 LOs are available to students in Mechanics, Civil Engineering, Architectural and other related cycles in Universities of Applied Sciences (UAS), Universities and Technical Universities in Switzerland. Also, as no other similar tool is known to cover this topic, it is expected that the project can reach wide use all over Europe in higher education institutions with programs in this area. Contacts are already in place with some Italian institutions.

Each LO has a maximum fruition time of two hours. Following are three scenarios of use currently applied by project partners.

1. In a **blended learning** scenario within a bachelor course, the teacher can show the students the video of an LO and comment on it, and then assign the students the self-test and the normative part for autonomous learning, which can be discussed in the next class. Other related LOs will be retrieved from the repository by the students. This lecture schema can be reused several times along the course, moving online about 20% of the work.

2. In a **fully online program** (i.e., 100% online), the teacher can provide the students with a set of related LOs (e.g., all referring to the same Swiss standard, or all presenting tests on steel structures) along with guidance questions. Students can work on them and then present a report which can be discussed in a discussion forum.

3. Another interesting application concerns the use of online LOs for **preparing lab sessions,** which surely represents an extremely effective (perhaps the most effective) learning experience for the topic. Students can in fact study the norms regulating some tests and the principles behind it before coming to the lab so that they can be more focused and prepared during the experiment. In this way, the time spent for preparing a lab can be moved online.

TEMAS is currently used in bachelor courses at partner institution, and it has been used as fundamental tool for the short course of Mechanical Behavior of Concrete and Steel in March 2008 at the Faculty of Architecture of the University of Cagliari, Italy. TEMAS has currently become integral part of the program of the this university's course, Structural Analysis.

Quality development

Many stakeholders are involved in the quality evaluation of TEMAS, and keeping control of their practices is a key element.

The successful integration of LOs into teaching and learning requires teachers to review and partly redesign their courses, providing them with means to enhance student satisfaction and to give them more autonomy and flexibility. Also, teachers can use the repository as a platform for sharing experiences and teaching resources with colleagues.

Institutions also can take advantage of enhanced students satisfaction in terms of image and reputation, producing also a positive impact onto society.

The firsts experiences of use have shown an enthusiastic approach from students. Having web resources available makes it easy for them to learn some structural concepts at their pace, also freely exploring the repository.

Conclusions

The TEMAS project illustrated huge benefits to enhanced student experience and savings that the proper use of digital multimedia technologies can support in high education. Also, the project team had to work on the definition of standards for making the development of LOs smoother—moving from craftsmanship to a more "mass-production" style, concerning video editing, formatting, style of text, etc.

From an institutional point of view, TEMAS is aligned with the strategic goals of partner institutions, which value the use of digital technologies in teaching and learning. TEMAS developed a topic-specific online repository containing a set of independent and reusable LOs which can be adopted flexibly by different higher education institutions in Switzerland and abroad. The project experience also indicated that a repository is not a "canned product," but is rather a lively platform, ready to further enrichment with new multimedia resources. Content will actually be updated in order to fit the peculiar need of future academic courses.

Also, TEMAS delivered precious experiences of integration of digital materials into courses and curricula at partner universities. Thanks to its modular approach and adequate translations, the road is paved for progressive and substantial integration of LOs into academic curricula.

The next development of TEMAS is planned on two levels. Minor maintenance issues will be dealt with by recruiting graduate students and interns to develop new topics or tools and to update online resources as part of their programs. In the medium-term perspective, TEMAS was conceived to become a repository base for the establishment of a network of academic institutions working on materials and structures, and such a consortium could develop a proposal for European Union funded project in the frame of Marie Curie or Leonardo actions.

References

Botturi, L. (2004). Visualizing Learning Goals with the Quail Model. *Australasian Journal of Educational Technologies 20(*2), 248-273.

Cantoni, L. & Botturi, L. (2005). eLearning Meeting Modular Education, the Case of Learning Objects. *Revue Suisse de Sciences de l'éducation/Rivista svizzera di scienze dell'educazione / Schweizerische Zeitschrift für Bildungswissenschaften, 27*(2), 231-251.

Clark, R. C. (1999). Developing technical training: A structured approach for developing classroom and computer-based instructional materials. Silver Spring, MD: International Society forPerformance Improvement.

Lonergan, B. (1990). Understanding and Being: In E. A. Morelli & M. D. Morelli (Eds.),*The Halifax lectures on insight*. Toronto: University of Toronto Press.

SCORM (n.d.). SCORM Web site. Retrieved June 9, 2008, from http://www.adlnet.gov

SVC (n.d.). Swiss Virtual Campus Web site. Retrieved June 9, 2008, from www.virtual-campus.ch

Wagenaar, A., Scherpbier, A. J. J. A., Boshuizen, H.P.A. & van der Vleuten, C.P.M. (2004). The importance of active involvement in learning: A qualitative study on learning results and learning processes in different traineeships. *Advances in Health Sciences Education, 8*(3), 201-212. Springer Netherlands

Wiley, D. A. (Ed.). (2000). The instructional use of learning objects. Retrieved June 9, 2008, from http://reusability.org/