AC 2010-184: STORY-CENTERED LEARNING IN A COMPUTER-BASED SIMULATED ENVIRONMENT

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Story-Centred Learning in a Computer-Based Environment

Abstract - This paper reports on implementations of active learning strategies carried out for the civil engineering courses. Specifically, the activities are performed by students in a computer-simulated environment, in which they are assigned a role and follow a mission. As a consequence of the activity, the students prepare a product (a report, drawing, or other documents) and send it to a real tutor for evaluation. Because the simulation of the environment is the most expensive part of this class of development, a story-centered approach has been followed here, in which only part of the activities are represented in the module. This approach was originally proposed by R. C. Schank and has been adapted here for engineering education, in which formal modeling and calculations are part of the expected activities. Examples are used to illustrate the implemented activities, which refer to learning about structural failures. At the beginning of the module, the students are presented with a situation in which they play a role and have to investigate a collapse in order to identify the causes of the event. There is a virtual library room, in which supporting texts are provided to help understanding the technical aspects. There is also a virtual computer room. The students can ask virtual tutors about specific topics that are relevant to the task they try to perform. Several virtual tutors are implemented in each case, of which some are "storytellers" and others are "analyzers". This format is not intensive in multimedia and still it is capable of creating a realistic situation in which the student has to perform activities similar to those that are expected from experts in the field.

Keywords – active learning, civil engineering, computational tools, story-centered activities, structural failures

Introduction

This paper reports on implementations of active learning strategies carried out within the context of civil engineering education. The main question addressed in this paper is: How can we implement virtual learning-by-doing strategies so that students learn without the need to have a human expert on the topic in class?

The term "active learning" is often used to enclose very different activities, but according to Prince, "active learning requires students to do meaningful learning activities and think about what they are doing" [1]. There are several ways in which active learning can be implemented, such as collaborative learning, cooperative learning and problem-based learning, among others. The efficacy of student active learning has been investigated by a number of researchers, and reviews may be found in compilations by Prince [1] and by Froyd [2]. Prince found evidence that supports most forms of active learning. He concluded that different implementations of problem-based learning emphasize different elements and this makes it difficult to state general assessment of this approach; however, it seems that this "positively influences student attitudes and students habits; studies also suggest that students will retain information longer and perhaps develop enhanced critical thinking and problem-solving skills" [1].

Basically, the strategy of learning-by-doing supports that students learn by performing activities aimed at reaching a pre-established goal, and not by listening to an instructor in a lecture. Advocates of learning-by-doing stress the role of doing as part of preparing to perform in a profession. According to Schon [3], the main features of reflection in action are learning by doing, coaching rather than teaching, and creating a dialogue between coach and student. Effective forms of learning by doing in real laboratories have been implemented in Engineering Education, especially for capstone courses [4]. Alternatively, a methodology of building a simulated scenario, in which the student can learn-by-doing while interacting with fictitious characters (some of whom provide coaching), has been proposed by Schank [5] as an effective form of active learning. Most simulations described by Schank and co-workers deal with training to perform managerial tasks. A recent review on the potential relevance of this approach as part of the education of future engineers has been recently presented by the author [6].

In the early tools developed by Schank's group, simulations as close to reality as possible were developed, involving animations and multimedia; however, as stated by Schank [7], the cost of such implementations may become prohibitive if a realistic simulation is attempted. An alternative has been proposed in the form of Story-Centered Activities (SCA), which are also forms of active learning in a computer environment [7]. In SCA the participant performs tasks to reach a goal; however, SCA do not attempt to create fictitious characters or realistic situations to represent real life. As an example, Ref. [7] describes an M.S. course in which a mission is given to the student through an e-mail. This is the only communication between a fictitious character and the student, and includes details of what should be the outcome of the work performed as a consequence of the research (a report). In Schank's example, there is no navigation dimension (which is the most expensive part to implement in simulations). To help students do their work, guidelines and reading materials are provided for download from internet sites. The guidelines list the activities that should be completed in each case to achieve something. Examples of step-by-step guides may include: "Read through the analysis objectives and evaluation requirements listed in the e-mail; Download the template for the analysis and recommendation report; Download and read through the case material on the case"; etc. The final report submitted by the student should respond to specific questions, which include an analysis of a situation and recommendations about how one should proceed next. This form of active learning does not employ videos or recordings and is far easier to implement than a more realistic simulation. The evaluation of the report produced by the participant is made in an asynchronous mode. In broad terms, this may fall in the category of problem-based learning, in which a significant problem is posed to the students in order to provide motivation for learning.

There are several ways in which a student could receive help in order to complete a task. The main idea is that if a student is assigned a task but without having supervision, then there is a chance that she will never learn how to do the task correctly. A human expert is not always available to help each student while performing a task; thus, implementation of virtual tutors becomes desirable. The implementation of virtual tutors has been discussed by Schank and Cleary [8] and has been employed in this work. The student should ask specific questions to virtual tutors at the time in which she needs an answer; thus, it should be a decision of the student when she approaches the expert.

The activities reported in this paper are performed by students in a computer-simulated environment (rather than in a real laboratory), in which they are assigned a role and follow a mission to be accomplished in one or two hours. The next section describes details of a computer-based learning tool developed by the author to study structural failures in civil engineering. Reports of the activities performed by students while using the tool, and an evaluation of learning in a pilot group are subsequently presented. Sufficient details are given in each case to stimulate other engineering faculty to become involved in the development of similar SCA in their own fields.

Material and Method

This section describes details of one of the implemented SCA, which has been used in to learn about structural failure investigations in a course for senior undergraduate/graduate students. As stated by Delatte [9], the use of engineering failures to teach concepts to engineering students has been neglected in most US schools.

The typical screen of the implementation is shown in Figure 1. Under "Home" there is a brief explanation that states: "At the beginning of the simulation, you are given a role to play (for example, as an expert in the field, or as a professional capable of doing a job). You will learn about the problematic situation to be solved through communication with a simulated character, who requests your help to perform an action (i.e., do something; identify the causes of failure of the structure)."

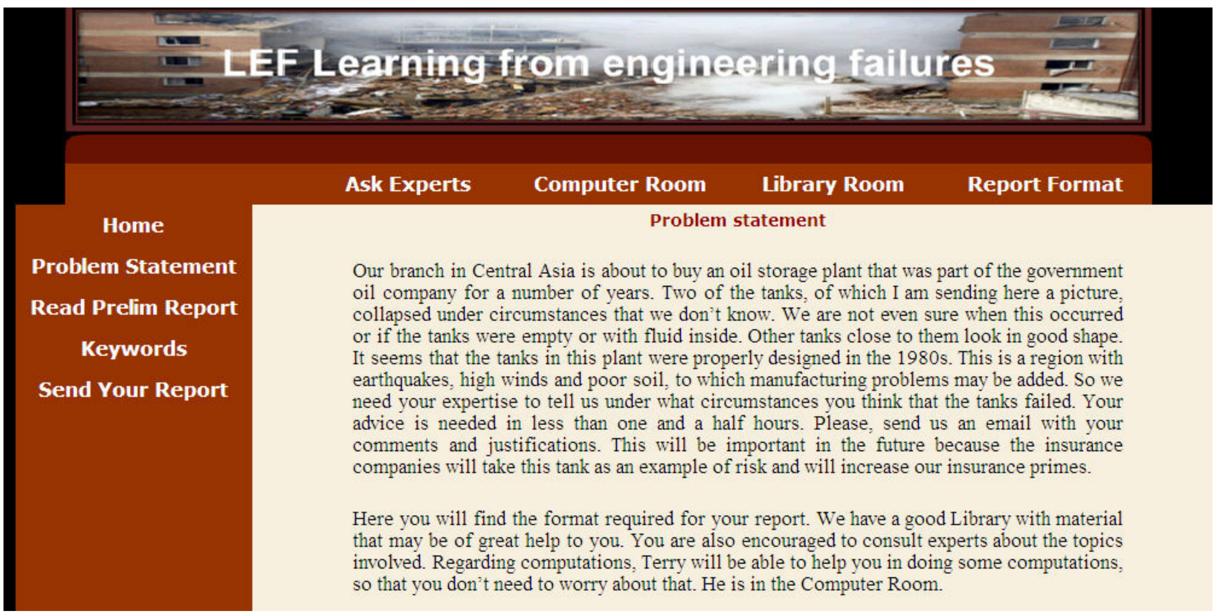

Figure 1: The problem assigned to the students includes a description of the mission and a few photographs that illustrate the structure that failed.

The problem statement of the specific activity reported in this paper is shown in Figure 1, in which a short story is told to introduce the problematic situation. This is a fictitious case, but at the same time it is representative of jobs that need to be solved in a short time. A photograph of the specific structure under consideration (not shown in Figure 1) is also given as part of the problem statement, together with a brief description of what can be obtained under the various headings of the site.

Under "Report Format" the students find the following specifications:
"Your report should include two topics:

- Identification of the cause of failure. Provide your own explanation about the cause of the collapse and explain the mechanism of collapse that may have occurred according to your own judgment and experience.
- Elimination of other hypothesis. Write the reasons why you consider that other modes of failure could not occur, discussing them one by one."

To support student's learning, there are two main sources of information: "Ask the experts" and "Library Room". Schank and Cleary [8] describe various forms of providing expert advice, of which two were considered as extremely valuable in our implementation: the "Story-teller" and the "Analyzer". A Story-teller is introduced to tell a specific story that is relevant to the task that the student performs, and tells stories, not general knowledge. Rather than using a narrative to tell cases, a story-teller can provide examples with illustrations that show how something occurs; this is how we have implemented a Story-teller in our case (i.e. providing examples of failed structures under specific conditions). The Analyzer, on the other hand, provides rules and generalizations, not cases. This is information typically provided in books or papers, but written in a friendly way. Interviews with experts to gather information about these topics were carried out as part of this research and are independently reported in a recent paper [10].

The "Ask the Experts" menu is composed of questions the student may ask to get expert advice. The implemented options in this case are shown in Figure 2. Because the role of the expert in this case is to show examples of failures, this part has been organized as a Story-Teller.

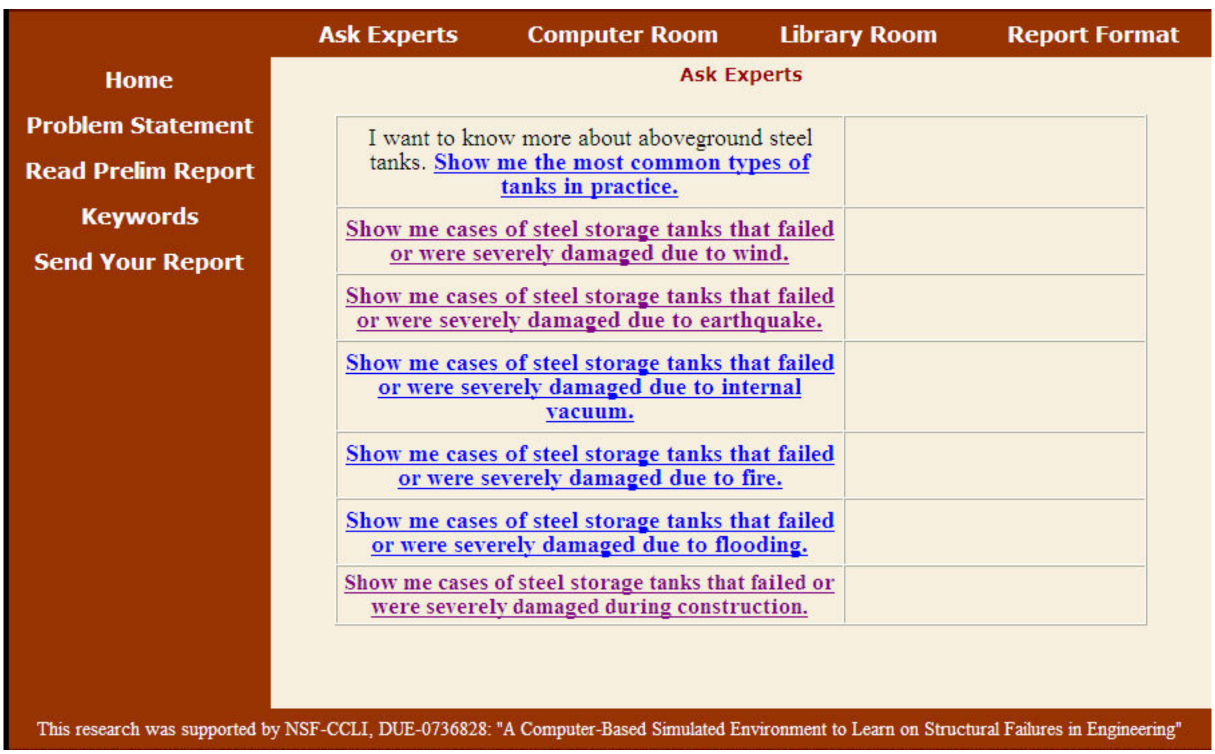

Figure 2: A screen for interaction between a student and a virtual expert.

As an illustration of the kind of expert advice provided, consider Figure 3. More cases of failures due to the same cause can be seen by scrolling down the page. At least four cases are included for each type of failure.

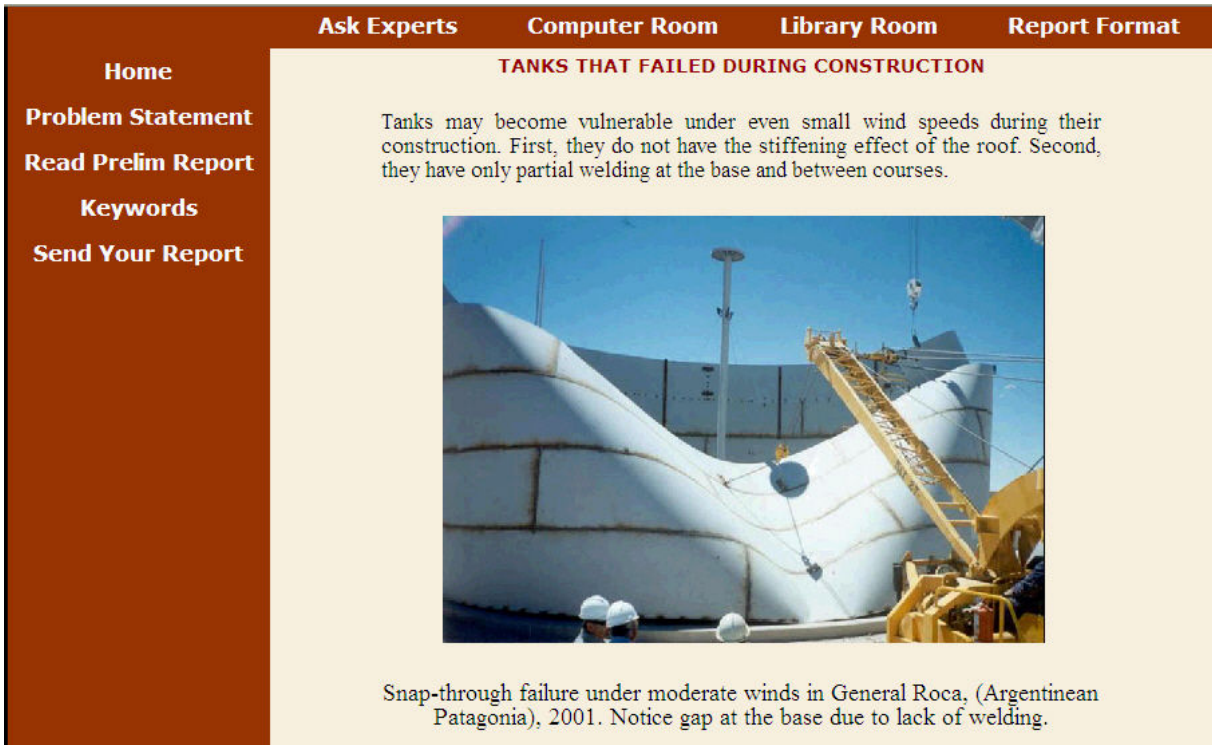

Figure 3: Screen showing expert advice that illustrates examples of tanks failed during their construction.

Another link leads to the "Library Room". In the opening screen, the student reads: "Hi, I am Borges, the librarian. I think I know what you are looking for. There are some texts that may be useful to answer your questions:

- A Primer on Structural Failures.
- A Primer on Buckling of Tanks
- The component elements of a tank"

This material was organized in three different formats to investigate which one was more attractive to the student. The first one was presented using the same format as in the rest of the tool; the second one is a document specially prepared for this activity but is presented in PDF format; and the third is a PDF file containing parts of a book chapter.

The "Primer on Structural Failures" was organized in the form of a virtual tutor, specifically as an Analyzer. The questions addressed in this primer were:

- What is a structural failure?
- What are the most common forms of failure?
- What is a failure analysis?
- What are the main concepts involved in failure analysis?
- What fails is a structural system, not just a structure

- Example of failure of a structural system
- Is there a method to find causes of failures?
- A methodology for research or a method for reporting?
- How do we formulate failure hypotheses?
- Can we test a hypothesis?
- How do we solve a puzzle?
- References

The material provided in this tutorial was obtained from books and was organized in a form that several sources were used to discuss each question. The sources were acknowledged in each case and listed as references.

Some of the links (such as the "Computer Room" and the "Preliminary Report" in this case) do not contain further activities depending on the specific SCA implemented. In the present implementation it was not necessary to activate the computer room, but this has been a key part in other activities. Rather than having the student perform the modeling by themselves, the Computer Room contains the results of a number of computations, some of which are necessary to construct a numerical solution.

Finally, the instructions on how to proceed at the end of the SCA are given under "Send your Report". Each student writes a short report using a word processor and attaches this file to an email which is sent to a real instructor.

Activities Carried out by Students during Their Work

Because this is a recent work done by the author, it has only been tried in one occasion (a normal class) and with a pilot group. At the beginning of the class it was mentioned that grading would not be assigned for this activity. Each student used one computer and the software was provided in a CD ROM. No questions were asked by the students and the activities were carried out in complete silence.

The activity lasted for almost 1.5 hours. To follow the use of time employed by the students while visiting each part of the SCA, we monitored what page they were visiting; this was easily done by hand because there were only five students. Table 1 shows the use of time for each student.

Initially all students read the problem statement and went next to the library for a short overall visit. Most of them went next to the section "Ask the Experts" to inquiry about examples of failures. All students completed the block on "Ask the Experts", and each visit to one failure screen lasted between one and two minutes. When writing the report, they often revisited the examples for less than one minute. On average, about ten minutes were spent considering examples of failures provided by experts. Two students spent a long time reading background material from the library room ("On Buckling" and "On Tanks"). The students who spent less time on background material were more interest in the library material on "Primer on structural failure". During the navigation, all students took hand-written notes on paper. Writing the report started at about 40 minutes from the beginning of the activity. Approximately half of the time was spent on navigation through the SCA and the other half on writing the report.

Table 1: Activity carried out by each student as a function of time. Minutes indicate time at the beginning of a five minute period.

Time [Minutes]	Student A	Student B	Student C	Student D	Student E
0	Problem statement	Problem statement	Problem statement	Problem statement	Problem statement
5	Library; Ask the experts	Library; Ask the experts	Library; Ask the experts	Library; On buckling	Library; Ask the experts
10	Ask the experts	Ask the experts	Ask the experts	On buckling	Ask the experts
15	Ask the experts	Ask the experts	On buckling	On buckling	Ask the experts
20	On failures	On failures	Ask the experts; On tank comp.	On buckling	Ask the experts; On tank components
25	On failures	On failures	On failures	On buckling	On tank components
30	Ask the experts; On failures	On buckling	On buckling; Report format; On failures	On buckling	On tank components
35	On buckling	On tank comp.; Report format	On failures	Ask the experts	Report format; On failures
40	On tank comp.; Report format	On failures	On failures; Writing	Ask the experts; Report format; Writing	On failures; Writing
45	Writing	On buckling	Writing	Writing; On failures	On buckling
50	Writing	Writing	Writing	On failures	On buckling
55	Writing	Writing	Writing	Writing	Writing; Ask the experts
60	Writing	Writing	Writing	Writing	Writing
65	Writing	Writing	Writing	Writing	Writing
70	Writing	Writing	Writing	Writing	Writing
75	Writing	Writing	Writing	Writing	Writing
80	Writing	Writing	Writing	Writing	Writing
85	Writing	Writing	Writing	Writing	Writing

Time was not used in the same way by different students, as may be seen in Table 2. Clearly, the activity provides more material than needed and more than what one student could read/navigate in the allowed time. This means that the students must consider what is available and choose where they want to spend more time.

Table 2: Time [in minutes] per activity per student.

Activity	Student					Average
	A	B	C	D	E	
Statement	4	4	4	4	4	4
Report format	2	2	2	2	2	2
Library	2	2	2	2	2	2
Ask experts	15	13	10	7	17	12.4
On failures	12	15	12	7	5	10.2
On buckling	5	10	7	27	10	11.8
On tanks	3	3	2	0	12	4
Writing	45	40	47	40	37	41.8
						88.2

Evaluation of Learning

Evaluation of Reports on Failure Analysis

The reports written by the students were typically one page long, and addressed both points specified in the "Report Format". The quality of the student's reports was assessed by considering nine indicators of student's performance. An analysis of the answers provided by the students is summarized in Table 3. All observations in the table have been written as performances and in a positive way, so that a cross indicates understanding by a student.

Table 3. Analysis of the reports submitted after the SCA.

Student performance	Student				
	A	B	C	D	E
1. Correctly identifies the cause of failure	x	x	x	x	x
2. Correctly describes main features of other causes of failure	x	x	x	x	x
3. Cause identification is not based on elimination of other possibilities	x	-	x	x	x
4. Describes failure mode observed in the photographs (Collapse towards the inside, Very large deformations, Deformations around the circumference)	-	x	x	x	x
5. Identifies events that may lead to this failure	-	x	x	x	x
6. Relates current failure mode with those at other sites	x	-	x	-	-
7. Identifies that cause must be due to a local rather than global effect in the plant	x	-	-	x	-
8. Does not introduce unjustified reasons in an argument	x	-	x	x	-
9. Does not repeat information that was already given to them in the Problem Statement	x	-	x	x	x

Regarding the two goals set to the students in the Report Format, all students arrived at the correct identification of the cause of failure (Performance 1 in Table 3), and could discard other hypothesis (Performance 2) based on what they learned during the activity.

Additional observations are made concerning the submitted reports, and this leads to several performance indicators that may be used with a larger group of students. Most students carried out an adequate description of the geometric deformation of the collapsed structure (Performance 4), with details of what were the features that they observed.

Most students did not use the cases collected through asking the experts (including when and where they occurred) to write an argument in favor of their recommendation (Performance 6), nor did they identify that the cause must have been a local rather than a global factor affecting the plant under consideration (Performance 7). On the other hand, most students did not introduce unjustified reasons in their arguments (Performance 8), and did not repeat information that was already given to them in the statement of the problem (Performance 9).

An analysis of the reports of the individual students indicates that students C and D did an outstanding job, providing adequate answers in 8 out of 9 indicators. Student B, on the other hand, only provided 4 out of 9 correct answers. Of course, not all indicators should have the same weight, and the first two are the most important. They were correctly identified by all five participating students. It has not been possible to state significant findings linking student's performance (Table 3) with how much time they spent on each activity (Table 2). For example, students C and D, who obtained the highest scores, followed different paths and spent very different times navigating some specific items.

Pre and Post Evaluation

Pre and post-tests were conducted in order to characterize the knowledge that students had about structural failure investigations. The pre-test was conducted a week before the activity described in this paper, whereas the post-test was done after the activity. The questionnaire included seven questions:

1. What are the differences between "collapse" and "failure" of a structure?
2. What are the most common causes of structural failures?
3. What is buckling?
4. What is a failure mechanism?
5. What are the objectives of the failure analysis of a structure?
6. Is there a unique method to conduct an investigation into a structural failure?
7. What is a failure hypothesis?

Following the pre-test, the answers were classified to characterize the knowledge used by the students. The same categories were used in the post-test, but in some cases new alternatives had to be defined.

All seven questions were discussed in the tutorials available in the library of the SCA. Some questions were more directly related to the activity than others: For example, Question 3 inquiries on buckling and the failure investigated was due to buckling. The students observed a large number of pictures of tanks that buckled and had a tutorial on buckling (including a definition), so that answers had a significant change between pre and post-tests. Question 5 was also directly related because the students did a failure analysis as part of the SCA and could answer from another perspective in the post test.

An analysis of the responses shows a large dispersion of answers in each case in the pre-test. On the other hand, the answers became almost uniform for questions 1, 2, 3, 5, 6 in the post-test. Even if the "right" answer was not provided in the post-test questionnaire, more precise answers were given by the students. Instruction had the effect of relying less on intuitive ideas. In some cases, more than one category was included by one student and both were recorded without establishing a hierarchy.

Student evaluation of the activity

Five questions were asked to the students after the activity in order to have their opinion on different topics and improve the SCA. The questions were:

1. Did you find it more difficult to read a PDF file than the rest of the screens?
2. Do you find that the material provided was excessive for the available time?
3. Do you think that some material was superfluous?
4. What was the most useful material that you consulted?
5. Do you think that you learned the same, more or less than in a normal lecture?

The responses were basically coincident. The students did not have any special preference about the format used to present the material (Question 1). They all acknowledged that the material was more than could be consulted in 45 minutes (Question 2), but did not complaint about that. One student wrote: "The material was a bit long for the time, but I believe that this is part of making this such a dynamic activity". Another student wrote: "I could not read part of the material due to lack of time; however, the time given to us was enough to read the necessary topics". Nothing was identified as superfluous (Question 3).

The most useful parts (Question 4) were those in which there were questions posed to the experts. One student wrote: "The photographs were great. It is not the same to read something than to see what is happening, and the photographs helped me to identify details of each failure and to distinguish among them".

Regarding Question 5, students answered that they could learn more than in a normal lecture. Examples of justifications were: "Because you are visualizing a problem and attacking it in a different way. This is more realistic", "I had to take immediate decisions in which I applied everything that I just learned on the topic". Similar findings have been reported by Schank [9].

Conclusions

A computer-based activity has been implemented to learn how to investigate structural failures using the approach of learning-by-doing. The tool was developed around a story in which the student plays the role of an engineer and needs to solve a problematic situation. This format is not intensive in multimedia and is still capable of creating a realistic situation in which the students perform activities similar to those that are expected from experts in the field. To create activities around realistic situations, the author has used his own experience as a consultant in failure problems and those by other experts in the field that were interviewed [10].

Only one activity is discussed in this paper in order to focus on the strengths and weaknesses identified during its implementation in an advanced undergraduate/graduate class. A pilot group worked using this tool during 1.5 hours in class and the learning process was monitored by means of pre and post tests, through an analysis of the report written by the students to solve the problematic situation, and by means of a questionnaire about their feelings after completing the activity. The students responded that they learned more than in a standard lecture because they needed the knowledge to answer something immediately. The implementation described seems to provide a satisfactory answer to the question posed at the beginning of the paper, in the sense that students could use this as a self-contained tool without the need to ask questions to a local instructor and at the same time, students accomplished the required tasks in the allowed time.

Because this is a pilot group, the lessons learned from this experience are only useful to test the workability of the tool and to improve its presentation. The use of time of each student was monitored during the activity and could be followed by hand with a small error. However this methodology of monitoring was identified as a weakness and should be substituted by an automated system if large groups of students work at the same time. All students reached a correct solution and could argue reasons in support of their recommendations to the fictitious client. Differences in the performance among students were detected in more subtle aspects of their report; and were useful to construct a matrix for the analysis of reports in larger groups.

Several activities have been implemented by the author and coworkers, mostly aimed at introducing the investigation of structural failures in courses that are not specifically devoted to that topic. Other cases include the collapse of a bridge truss in an industrial building (aimed at an undergraduate Structural Analysis course), the collapse of a reinforced concrete dome in a sewage digester tank (for a senior undergraduate course on Advanced Mechanics of Materials), and the wind-induced collapse of a steel storage tank [11,12] (for a graduate course on Plates and Shells). This illustrates that the same structure of the computer tool can be effective to implement activities in various fields of engineering. We envision implementing similar tools to teach ethics in engineering, and in a first year Physics course. Those activities are introduced as a way to enhance the sequence of lectures and introduce students to some realistic situations. In a typical course we would have this kind of activity once or twice in the semester, and we have not reached a stage in which a large part of a course could be delivered in this way.

This tool provides very different experiences from other learning strategies, such as giving the students a collection of readings and then have them write a report, because here the students can access just-in-time expert advice to solve a case that needs their attention. Emphasis in the tools described in this paper is not about writing a report but about solving an engineering problem as it may occur in practice.

Increasing the complexity or difficulty level of these tools depends on the difficulty of the assigned mission; however, as the complexity increases it is expected that more expert advice would be needed to support students learning.

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