ACTIVE LEARNING IN A SIMULATED ENVIRONMENT

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Abstract. This work emphasizes novel ways to teach and learn which can be developed by most instructors provided that they have the patience and interest to produce class innovations using computers. The specific approach discussed in what follows is known as “learning-by-doing in a virtual environment”. This is an approach initially explored by Roger Schank since the 1990s with emphasis on learning for the workplace, and it has been adapted by the author to address engineering education. Schank proposed that learning which is done in a computer should involve the participants in such a way that they perform a task to accomplish a mission assigned to them. The basic idea is to train students to do sophisticated tasks in a way similar to what an expert would do, and the only way to verify if the learner has learned a lesson is to ask her to perform a task in specific situations. The general conclusion is that in most cases a young student cannot learn in the real world because failure to perform up to a standard has severe consequences and may lead to high costs. Thus, one is left with a simulated situation in which the student may perform in a virtual world and there are no consequences if she makes a wrong choice or follows a wrong path. The center of this approach is the detailed reconstruction of a case, so that the students can perform some activity, such as role-playing, further explorations, etc. The general format of all tools developed in this research as learning modules include a problem statement, in which the participant is informed of the specific task that is required to be accomplished by her. If the participant accepts the challenge, then the system allows multiple paths to be followed in order to gather information and expert advice. There is a virtual library, in which literature related to the case is available; a computer room, in which computations can be carried out to obtain data for the case; there is expert advice, in which typical questions related to the topic are responded by experts in this field; and there is a navigation dimension, in which the participant can interact with the case by means of asking questions to virtual characters, exploring data specific for this case, going to a virtual field, and others. As a result, the participant should provide her response to the problem statement which originated the study. Construction of the navigation tool is made by means of a web-page with a tree structure. A number of simulations have been implemented, with differences in contents and also in complexity.

1 INTRODUCTION

Teaching science and engineering is not what it used to be. When I was an undergraduate student in the 1970s, most of the lectures that I attended were delivered using only one technology based on chalk and blackboard. A good teacher was one who could explain the topics following a logical sequence, so that we could reproduce the same contents and equations in the final (oral or written) exams. We studied to pass each course and were not concerned with our future roles as engineers or scientists. This situation was not restricted to the place and time in which I studied engineering, because I found the same teaching approach at the university in which I studied for my doctoral degree, and most readers would identify this approach in different departments at present.

At some stage, it was recognized that not all students learn everything in the same way: there are different learning styles (see, for example, Dede, 2004). Some students feel more comfortable if they can work in groups cooperating with peers; others prefer to investigate a topic by themselves; some students prefer to listen, others are better at reading. This new understanding of how people learn (which is summarized in Bransford et al., 1999) has been the subject of research in education, with the consequence that different learning styles are now emphasized as valid (and desirable) forms of learning.

A second change has been the introduction of personal computers as part of our lives. The good news are that most university students have a laptop that they carry with them every day, and internet connections waiting for them at every corner. There are new opportunities to learn using different computer-based environments. On the other hand, it is easy to find that most educational material available in Internet is very similar to the old textbooks, in the sense that the student is expected to read some text and fill a multiple choice test to verify what she can remember.

And there are even more changes: the contents have changed in unexpected ways. Before, the responsibility of a teacher was to teach methods of analysis and provide exercises for practice and testing. The new accreditation rules (such as ABET in the USA and CONEAU in Argentina) require that the student should perform well in a professional environment, hence the need to create realistic professional situations in which the student should perform, instead of traditional exercises.

This work emphasizes novel ways to teach and learn which can be developed by most instructors provided that they have the patience and interest to produce class innovations using computers. The specific approach discussed in what follows has been called "learning-by-doing in a computer-based (or virtual) environment". Although we acknowledge that "Active Learning" (see, for example, Johnson et al., 1991) is not the same as "Learning-by-Doing" (see, for example, Schank and Cleary, 1995), we abbreviate this methodology as ALSE (for Active Learning in a Simulated Environment). In essence, this methodology is based on the study of cases (such as in the textbook by Kolodner, 1993), and within the context of education, this classifies as Problem-Based Learning. A recent European review of PBL may be found in the book by Du et al. (2009).

The paper reviews the approach initially explored by Schank (1995, 2002a, 2005) since the 1990s with emphasis on learning for the workplace, and its adaptation to engineering education (Godoy 2005, 2009a, 2009b, 2010, 2011). The possibilities of this methodology in the field of Computational Mechanics are also discussed.

2 DEVELOPMENT OF ACTIVITIES IN A SIMULATION ENVIRONMENT

2.1 Basic postulates

Schank's approach is about active learning, and its main postulates may be stated as (Schank 2002):

- Training that is carried out on a computer should involve some form of simulation, in which the learner plays a role in doing something. "Doing" in this case must be some form of action on a situation which is relevant to the job.
- The environment should be designed so that it can provide the learner with several ways to support the learning.
- Failure is an essential part of e-learning, so that a simulation should provide the learner with situations in which she can make mistakes and fail. This can be achieved by including information that may lead a novice to form premature erroneous conclusions.
- The learner should be able to ask questions to an expert when she needs it more, that is, when she has failed or is about to fail. If a situation does not result as expected, then it brings questions to the people who attempt to understand the situation.
- A learning environment may be effective if it is related to the interests of the students.

The term "simulation" is employed here, but its meaning does not reflect the common use in the field of Computational Mechanics. Simulations are special type of models in which a process is represented. According to Allessi and Trollip (2001), there are mainly four categories of simulation in science education, depending if the aim is the representation of (i) physical systems, (ii) procedures, (iii) processes, or (iv) situations. Shank's approach refers to the last category, namely the simulation of situations.

2.2 General Organization of a Simulation

At the time we started working in this project, the main information available was Schank's theoretical considerations and a few examples of screens from the simulations published in his books. However, those references do not explain the way an implementation could be carried out, so that this discourages the application of ALSE methodology to new cases.

From there, we wanted to implement simulations relevant for graduate and undergraduate engineering students. The specific details of the contents are not relevant in this section, so that we will emphasize the proposed organization for a generic new development.

We propose to organize an e-learning module considering six dimensions (Godoy, 2005), as illustrated in Figure 1:

- The statement of the problem.
- The interaction of the learner with the case.
- The interaction of the learner with other participants (mentor and/or other students).
- The activity room.
- The library room.
- The response provided by the learner.

Next, we review the material related to each one of the six dimensions.

2.3 Problem statement

E-learning courses should start with a high impact element that draws the attention of the participants. In a typical simulation, a role is initially assigned to the participant and a scenario is presented with a problem that the participant must confront (this constitutes the mission).

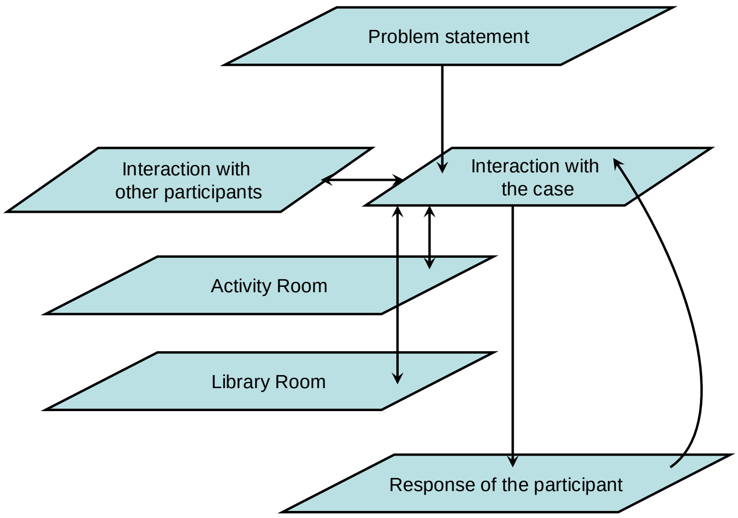

Figure 1: Proposed general organization of the simulation.

The problem can be stated by a special fictitious character, here called the Problem-Teller.

Decisions should be made from the beginning. For example, in one of the simulations, the participant works as a young programmer in a software company (role), who must develop a code to solve the problem (mission). In another situation, the participant is an art expert (role) who must provide advice to a museum curator on whether some of its paintings are fake (mission).

Once the mission has been posed, the participant can respond as follows:

- “I am ready to start”. In this case, she advances to the navigation dimension through the case.
- “I need help before starting”. In this case, a menu of help is provided.
- “I do not have any idea how to start”. In this case the most frequent questions are shown, guides on the process, examples, design specifications, among others.

2.4 Navigation through the case

The next stage entails participant interaction with the case. This is done through a series of situations in which the participant interacts with virtual characters which are shown in each screen, and actions that can be performed by the participants in response to them. This stage is denominated as “navigation” through the case. An illustration of an organization using a “tree” structure is shown in Figure 2. It is important that there are branches so that the participants may choose on whether to follow different paths and for each one, the module should provide different experiences or information.

Understanding the basics of this approach may be facilitated by viewing some examples. Figure 3 shows a screen during navigation which illustrates the elements composing it.

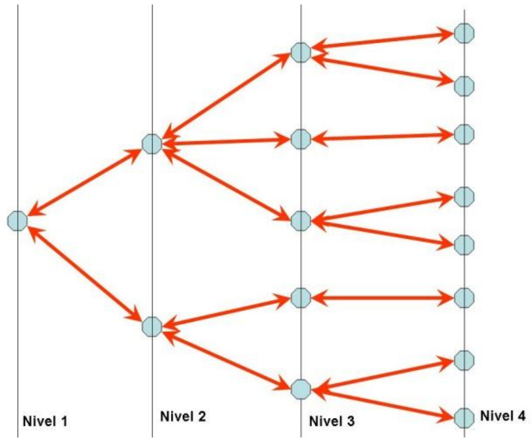

Figure 2: Navigation is organized in the form of a tree. Each node indicates a screen in which the participant may perform actions. Each arrow indicates possible paths to follow the module.

Figure 3: The Problem-Teller describes the task to be accomplished by the participant. As a response, the participant may follow several actions which are specified in the screen. For each action there is help addressing the convenience (or lack of convenience) of each action.

A character describes a problematic situation in which the participant will play a role. The description is followed by several possible actions implemented on the screen. Following an action may have positive and negative consequences, and the screen provides support to understand the convenience of performing such action: As a way to help the participant, next to each action there is a button which serves as an aid to identify pros and cons of following a specific path (a virtual tutor or "trainer", as will be seen later on). Moreover, there is a "Request Help" button for the whole page.

The participant can also pick if she wants to see an analysis of the actions which have been performed up to this point. She can also go back and redo actions.

The intervention of a virtual character can be implemented by means of a photo plus text, photo with audio, video, video and text, or any combination considered convenient; this will depend on time and resources available to the teacher/developer. The pros and cons of performing a specific action could be provided in the form of a text, an audio or a video. However, the action is always text that enunciates what action could be done. If the situation is a conversation with a character, the actions will be phrases that the participant could say next. Here is the "doing" part of the participant.

This is not the only format in which ALSE may be implemented, but in essence it requires building a scenario and allowing the participant to perform activities under a set of possibilities previously established by the designer.

As Schank (2002a, pp. 46) describes, each scenario that is shown to the user presents a global vision of the situation and offers the opportunity of doing a research of the context through specific resources under the simulation. Nevertheless, those resources are only available by demand, meaning that if the participant does not want to consult them and decides to go along ignoring them, she can do that, but the scenarios will be more difficult if she does not know the previous context in which an actual situation occurred.

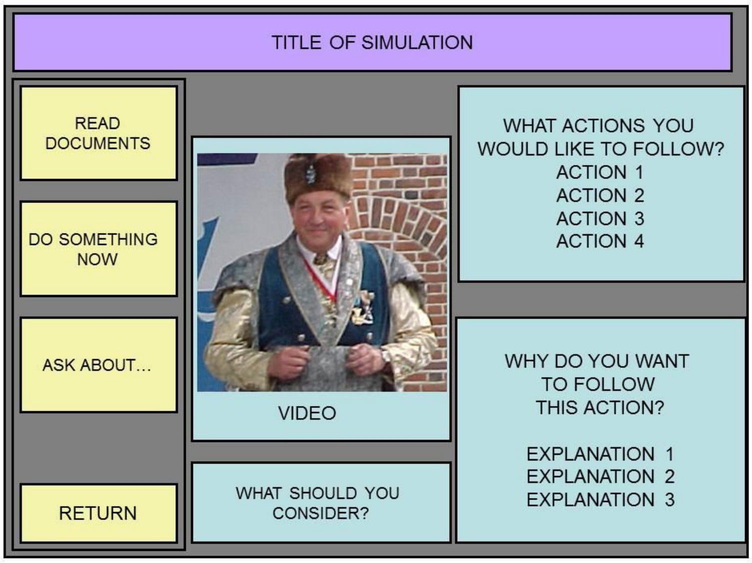

Figure 4: The participant may perform various actions in this screen, such as exploring available documents, doing a specific action or posing a question.

2.5 Case Solution

After navigating the situation according to what was shown and having collected sufficient elements, the participant must draw conclusions on the case. The solution of the case should respond to the problem stated at the beginning: This could consist of making a judgment or suggesting what has happened based on interpretation, deciding a course of action, or generating a product that was asked for in the introduction.

The most common form of presenting a solution is to show a series of predetermined alternatives so the participant can choose one. This limits the possibilities and channels the solutions towards the ones originally envisaged by the module designer, yet this approach is simple to implement.

Another possibility is for the participant to navigate the case, but to complete the mission the participant must write an original document (either a report or a product) and submit it to evaluation. This approach is especially convenient in problems that do not have small number of possible solutions, and in cases where things are not black or white but have a range of possible grays. For helping the student to write the document, it is convenient to provide brief examples of similar documents to the one the participant must produce, or provide the format expected.

2.6 “Observe and Critique” Alternative

Another possibility is creating a scenario where the participant is not one of the actors but observes a believable and conflictive situation to later on evaluate and counsel one of the virtual characters on the course of action that should be followed (this is described, for example, in Schank, 2002, pp. 145). In some cases this could provide more space and freedom to the participant by not putting her directly on the spot of the situation. As a consequence of the advice provided by the participant, the system shows the consequences of following such path. This could be done using text or videos.

In the simulations shown in books by Schank, the participant decides her actions based on a limited number of possibilities that are suggested. One could also open the possibilities to let the participant generate her own actions (writing what she wants to do or ask for); however, the algorithm would get far more complicated.

An alternative to show all the possible actions immediately for selection could be to allow the participant to think and then ask to see the actions foreseen by the system. Moreover, a selection structure could be implemented and the participants would be able to choose an action, and explain the reason for choosing it among all the other possible explanations.

3 WAYS TO SUPPORT LEARNING BY MEANS OF VIRTUAL CHARACTERS

Interventions must be given with fair and on-time support, when the person needs them because she has tried, failed, and needs further help. These interventions can be implemented by introducing simulated tutors of diverse nature, so that it is convenient to unfold virtual tutors by means of a variety of characters. Some of them are described next.

The Storyteller is an extremely useful character to provide information and to enhance attention in the participant. He/she shows up to tell a story that is relevant at a specific stage in the module. The Storyteller presents cases (not generalizations) and uses the case-architecture. Interaction with the Storyteller could be implemented in simple or complex ways, including the possibility that the Storyteller narrates parts of the story only at the request of the participant, as illustrated in Figure 5.

The Analyzer is another useful virtual character: she provides information in the form of rules and generalizations, not in a case format. The Analyzer provides information to continue forward in the module. The information provided by an Analyzer could be typically extracted from books. It seems advisable for the Analyst to intervene for something which is local and specific (instead of interfering few times for general aspects). The interaction with the analyst could also have details, as shown in Figure 5.

The Coach does not provide cases or rules but helps to decide which paths are worth following. For example, if the participant has doubts whether she should go to a place (such as a construction site), the Coach reminds her of the advantages that this action might have towards the stipulated goals.

The Evaluator does not provide cases, rules, or paths, but helps understanding the consequences of the actions adopted, and provides feedback on the participant’s progress. For example, if the participant decides to subcontract somebody to fulfill the task assigned to her, the Evaluator will inform the participant that by doing so she will lose the job because this is not an acceptable action in this context.

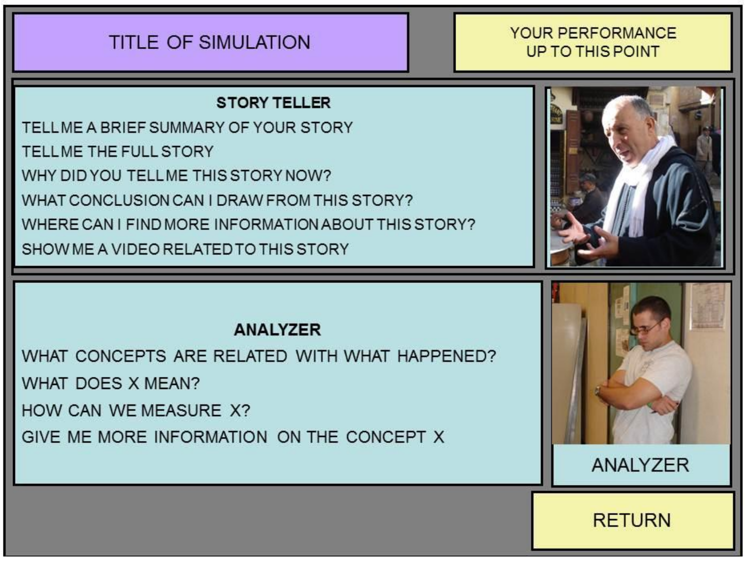

Figure 5: Two virtual characters: The Storyteller and the Analyzer.

Finally, the Teacher (see Figure 6) teaches something specific to the participant, in the form of a short lecture. In the screen discussed in Figure 6, the Teacher teaches buckling concepts in an organized way, by addressing a short number of topics which are relevant to the solution of the case. Sometimes it is good to explain who is the virtual character (the Teacher in this case), and if the participant enjoyed learning from this character she may be interested in learning what other topics could be learned from the Teacher. Or she may be interested in reading more on this topic.

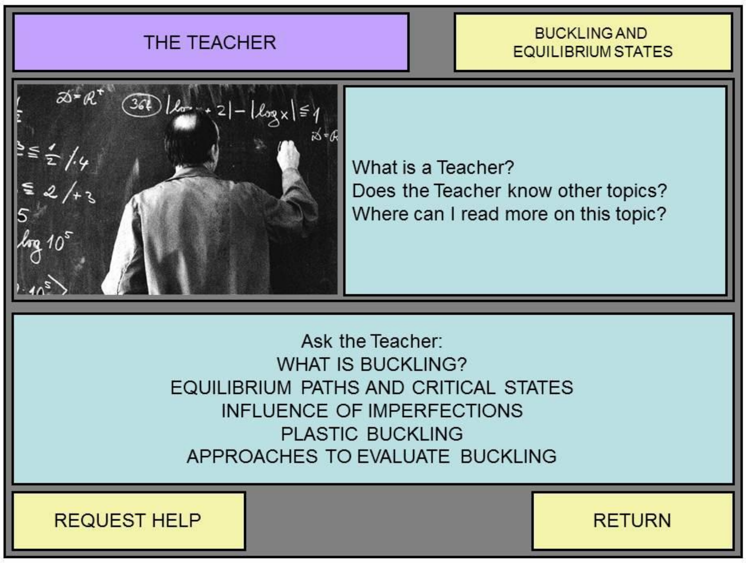

Figure 6: The Teacher. In this case, the virtual character Teacher explains buckling concepts, and the participant may request answers to pre-established questions. The participant may be interested in other topics that the Teacher knows.

4 EXAMPLES OF MODULES

To illustrate the type of problems posed to students in an undergraduate Civil Engineering class, consider the following case. The story is explained in the Problem Statement, which reads:

"Mr. Michael Rhodes, the young engineer just hired by our firm, has produced the following preliminary report concerning the failure of two structures that a customer brought to investigate. In reading this report, we found a number of problems and inaccuracies. Please, go through the case, do your own calculations, and send Michael an e-mail explaining the problems that you found in his report and how they should be corrected.

Here you will find the format required for your report. We have a good Library with material that may be of great help to you. You are also encouraged to consult experts about the topics involved. Regarding computations, Terry will be able to help you in doing some truss and frame computations, so that you don't need to worry about that. He is in the Computer Room."

Next, the participant can read the report cited in the Problem Statement. This starts as shown in Figure 7. The required computations would not be completed in the time allocated to this activity (which is one hour). Hence, an alternative is to provide a set of results with which the participant can carry out the analysis. This is shown in Figure 8.

The activity described before has been employed in a Civil Engineering course of Structural Analysis at an undergraduate level. A total of 20 students participated in the activity, which was scheduled to be solved in a computer center and lasted for 90 minutes.

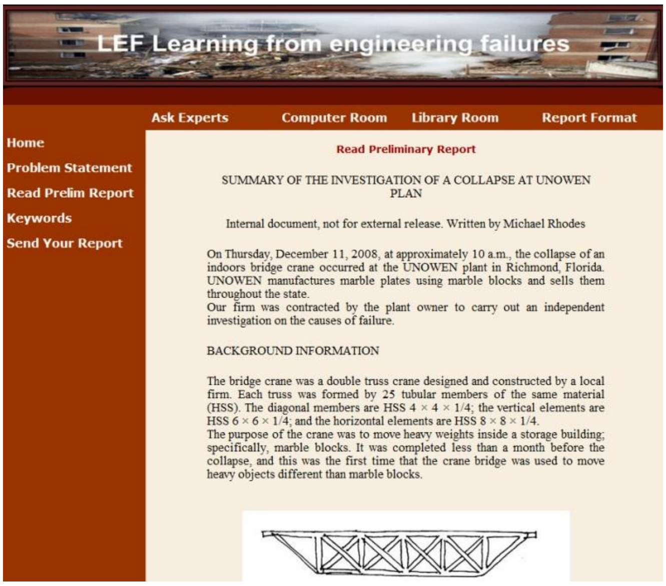

Figure 7: The existing preliminary report with which the participant should work.

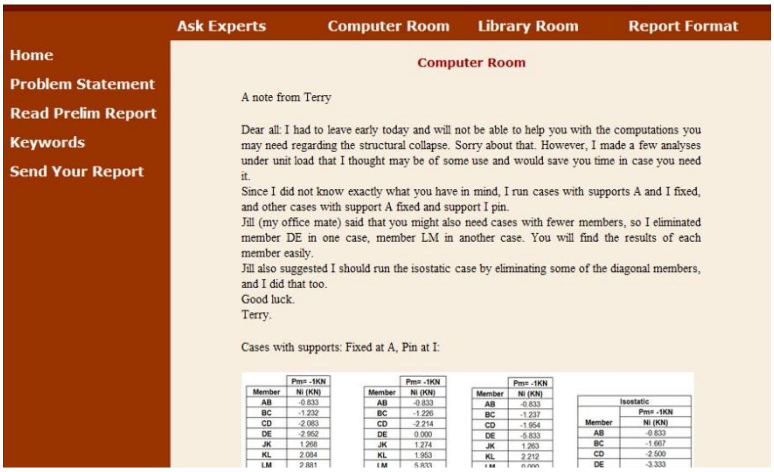

Figure 8: The Computer Room.

An important part in this activity is the help that the participant may get while running the module. A schematic view of the help in the form of “Ask the Experts” is shown in Table 1.

Table 1: Example of “Ask the Experts” in a module.

Ask Prof. Hibbeler about Determinacy and Stability	*Who is Prof. Hibbeler?*
Ask Prof. Hodge about failure analysis of trusses	*Who is Prof. Hodge?*
Ask Prof. Hodge: Why the elastic carrying capacity is an artificial definition?	
Ask Prof. Neal about basic concepts and assumptions in failure analysis of frames	*Who is Prof. Neal?*
Ask Prof. Horne about plastic failure of frames	*Who is Prof. Horne?*
Ask Prof. Horne: What are the limitations of failure analysis of frames?	

Our branch in Central Asia is about to buy an oil storage plant that was part of the government oil company for a number of years. Two of the tanks, of which I am sending here a picture, collapsed under circumstances that we don't know. We are not even sure when this occurred or if the tanks were empty or with fluid inside. Other tanks close to them look in good shape. It seems that the tanks in this plant were properly designed in the 1980s. This is a region with earthquakes, high winds and poor soil, to which manufacturing problems may be added. So we need your expertise to tell us under what circumstances you think that the tanks failed. Your advice is needed in less than one and a half hours. Please, send us an email with your comments and justifications. This will be important in the future because the insurance companies will take this tank as an example of risk and will increase our insurance primes.

Here you will find the format required for your report. We have a good Library with material that may be of great help to you. You are also encouraged to consult experts about the topics involved. Regarding computations, Terry will be able to help you in doing some computations, so that you don't need to worry about that. He is in the Computer Room.

Figure 9: An example of Problem Statement for a graduate Civil Engineering course.

A second example of problem developed by the author involves concepts of shell buckling and has been employed in graduate courses (Theory of Elastic Stability and Advanced Mechanics of Materials). In each case, a small group not exceeding 10 students participated in the activity. The activity was planned to last for 90 minutes, and was carried out using the students' own personal computers in a classroom.

The mission assignment for this second case is shown in Figure 9. The participant has to identify a failure mechanism of a shell, with elements based on the deflected shape of the shell at failure. This is a good opportunity to learn about deflected modes under various load scenarios, and the student is here provided with a number of examples of other similar shells that failed in the past under seismic, wind, pressure, fire, support settlement… No computations are involved in this case, because the nature of the module is centered on qualitative identification of modes.

A number of modules have been developed by the author, and they are reported in the literature. One of the implementations emphasize the role of history in the learning of mechanics (Godoy, 2011); others address the analysis of failure mechanisms in structures (Godoy 2009b, 2010) and fire effects on structures (Batista-Abreu and Godoy, 2011).

5 COMPARISONS WITH RELATED METHODOLOGIES

Different authors have proposed approaches which can be related to the present ALSE methodology, and two of them are discussed in this section.

Role playing in the form of problems to be solved by students are (not often) employed in textbooks. As an example, consider the Exercise at the end of a chapter in a book on Fracture Mechanics:

"As a failure expert, you have been called to resolve a dispute between a customer and a manufacturer of a crane hook that failed in service. The customer contends that the hook failed because of a flaw and offers as proof the fact that the fracture surface of the failed part has an obvious crack with an area of 0.35 square inch (see Figure E7.2). The manufacturer counters that damage-tolerant design concepts were used in the design of the hook, and a crack of this size would not lead to failure. The manufacturer counterclaims that customer exceeded the maximum load rating of the hook of 4000lb. To aid in the analysis, you conduct compliance tests with machine flaws of 0.30 and 0.40 square inch. The test results are shown in Figure E7.2. The hook is made of steel (E=30,000,000psi and Poisson's ratio 0.29) and has a plane strain fracture toughness of KIC = 40 ksi √in. Using this information, who is correct? Justify your answer." (Sanford, 2003, pp. 250).

This is an interesting problem, in which the student should consider the competing explanations for the fracture failure of a metal component; however, this is used as a posteriori of learning, i.e. once the main concepts have been grasped in the chapter, the problem acts as an application. The ALSE methodology, on the other hand, works as an a priori approach, in which the role-playing and the activity are used as a way to learn the contents. Rather than leaving the learning stage for the previous lectures or chapter reading, the same problem could be employed in the ALSE approach as the Problem Statement, from which the other dimensions of the approach (shown in Figure 1) can be constructed.

On-line role-playing has been used by other authors in the context of engineering education (see, for example, a recent paper by Cobo et al., 2011). Such approach also emphasizes "choosing a relevant role related to the professional future of the student. This way, the specific competences to be developed will be derived from a real work situation, and will be perceived as important and motivating for the students." A mission is assigned to the participating student, but there are no self-contained modules, in the sense that no teaching is done within a module, as in the present approach. Communication with the tutor is done using e-mails. Technical material is available on request, in the form of documents (this would be equivalent to our library dimension). Significant differences are the presence of expert advice in ALSE tools, and the navigation dimension, in which the student can interact with the case.

6 CONCLUSIONS

Along the three years of this project we developed on-line tools based on the approach of Active Learning in a Simulated Environment (ALSE) to teach engineering failures and lessons which can be learned from them to improve design. The effort concentrated on low-cost educational tools that could be developed without having access to large funding and resources, as would be the case of most engineering faculty interested in the extension of this approach to cover their own interests.

Based on our experience in implementing ALSE tools in Civil Engineering classes, we found that undergraduate and graduate students were able to complete the proposed activities without the need to have an experienced faculty member available to coach or help them during their work. This is important because it marks a difference between learning tools that require the presence of a human tutor (who knows about the subject contents) helping the student along the way, and a more autonomous tool (as in the present case) which can be used at a different location from the place where the tool was originally developed. The moduli developed under the present project are self-contained in the sense that the participating students carry out the tasks without the need to consult a faculty member during the activity because the tools provide on-line virtual tutors to help the student with just-on-time expert advice. The importance of this finding is related to the portability of the tools, so that they can be used at other locations by other faculty members.

From the application of ALSE tools developed under this project, we learned that students perceive that they learn more than in a traditional lecture. The reasons expressed in questionnaires and interviews are because they have to apply the new concepts immediately (rather than differing their application to a later stage), and because they had to learn new concepts motivated by the fact that they need such concepts to solve a problem that has been posed to them. Further, they enjoy this form of activity because they like to be placed in the role of active investigators rather than being passive listeners. They state that they can construct the knowledge that they need by doing research oriented to the solution of a problem. Finally, students can associate knowledge with a story in which they play a role, rather than storing knowledge in a vacuum, and in this way our study shows that they increase learning retention.

Regarding learning assessment, the performance of students employing ALSE tools can be evaluated in order to establish differences in performances among students (Godoy and Valeiras, 2011). Not only pass/fail grades can be used as evaluation, but more subtle differences in student learning can be identified based on their response to the challenge posed to them.

In all cases the activities lasted between one and two classes. On the other hand, the author has never attempted (nor does he recommend) implementing a complete course based on the ALSE methodology, because this would be a single learning style and would lose the advantages of offering different learning styles in one course.

Our experience shows that perhaps the most complex part of implementing this approach for first-time users is the construction of an appropriate story. The topic is discussed in Godoy (2011), and much can be learned from the storytelling tradition in education, such as Egan (1986).

Some of the current limitations in our implementations involve the lack of interaction between students during the on-line activities. It has not been possible to the author to implement this dimension in a simple way until now, and this is considered work for improving the present or future modules.

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