TEACHING AND LEARNING NUMERICAL CALCULUS AND ITS APPLICATIONS WITH CAN

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ABSTRACT
CAN is a part of a five-year program meant to create multimedia software tools that offer teachers the possibility to build and present their e-learning applications (courses, seminars, laboratories and exams) in a hypermedia way. CAN acts in two directions: teaching and learning numerical calculus/analysis, and applying theoretical knowledge in petroleum engineering. The main goals of this package are to support a more active teaching and learning, to encourage students to understand deeply the theoretical concepts, and to reflect on them and on their practical applications.

KEYWORDS
Teaching and learning, models of professional education/practice, the competency-based model, the reflective practice model, e-learning

INTRODUCTION

The resources available for the delivery of instructional materials to students in higher education have been considerably reduced over recent years and will continue to do so. During the same time, the number of students entering higher education has increased substantially. Clearly, there is an acute need for cost-effective solutions to provision of high quality teaching and learning materials. These must enhance the learning experience for students. E-learning can be an effective tool for this goal. E-learning, in theory, lowers and even removes the two biggest traditional barriers to a learners' continuous learning and improvement: time and money (Schank, 2002, Vladoiu 2001). In reality, of course, e-learning – as any other learning experience – is frequently derailed by flawed methods and materials.

However, with proper design and implementation, e-learning applications can overcome such danger and provide to students an environment in which they can safely and repeatedly test out a variety of assumptions and scenarios to progress rapidly toward the learning goals. Thus, well-designed e-learning provide the best opportunity for student self-guided learning. It is self-paced and self-planned, with students themselves choosing their own paths through the mass of information encompassed by the e-learning packages. Successful use of such packages will not only increase students' knowledge, but will require them to develop other important skills, including self-assessment and planning of studies, information technology skills, creativity and self-motivation. The role of teacher will change from dispenser of knowledge to coach, facilitator, and mentor, and the student will take advantage of anonymity on help seeking and on self-assessment. A new teaching and learning paradigm is emerging.

Development of information technology, in particular, hypermedia networks, emerging instructional digital libraries and virtual reality techniques, makes it possible to establish new models for teaching and learning (Vladoiu, 2001). These models have new capabilities such as:

- learning patterns and environments will change from groups to individuals. However there will be the possibility to learn and work within virtual teams;
- open environments will replace restrictions regarding the spatial and temporal limitations for the classroom. This will provide for worldwide distance education;
- passive learning will be transformed to reflective active learning;
- dependence of physical equipments will be reduced to a minimum;
- source of knowledge will not be simple anymore, but multiple;
- periodic current studying pattern will be replaced by a lifelong learning model;
- various learning/training contents and patterns can be changed quickly;
- improving the abilities of learners, rather than simply offer knowledge;
- main education goal will be obtaining the ability to reflectively acquire/apply knowledge.

In order to start implementing these modern models and methods for teaching and learning in our university, five years ago we started a new program called "Multimedia Integrated Model for Active Learning". The program goal was the creation of multimedia software tools that offer teachers the possibility to build and present their learning applications (courses, seminars, laboratories and exams) in a hypermedia manner (Vladoiu et al., 1997). CAN is a part of this program, concerned with teaching and learning numerical calculus and analysis. In addition to that, CAN provides for applying theoretical knowledge in petroleum engineering.

THE NEED FOR E-LEARNING PACKAGES IN SCIENCE EDUCATION

Science degree courses have many purposes: to provide a background of scientific understanding, to contribute to general intellectual development and to produce potential professional scientists. There is evidence that students on science courses can "learn" a lot of information, but understand little of what they have learnt. Furthermore, science students can have little time to reflect on or to consolidate their understanding (McAleese, 1997; Brockbank and McGill, 1998; Schank, 2002). More and more students are approaching learning at surface (to cope with course requirements) or strategically (to achieve the highest possible grades), instead of having the intention to really understand knowledge thought and to reflect on it and on the learning process (deep learning) (Light and Cox, 2001).

The term reflection is used with two meanings. One would be the process by which an experience, in the form of thought, feeling or action is brought into consideration (while is happening or subsequently) and the other the creation of meaning and conceptualization from experience and the potentiality to look at things from another perspective (critical reflection) (Brockbank and McGill, 1998).

Further, on we list some examples: the Institute of Physics from London, UK, has produced a document called "The Future Pattern of Higher Education in Physics" (IOP, 1990). This document concluded that many students understand much less than they are supposed to and most have had little time to reflect or build on their understanding. Long, Pence and Zielinsky (Long et al., 1995) argued that students do not retain very much of what they hear in a lecture, and that opportunity for reflection is essential. Nicol, Kane and Wainwright showed that students often learn ineffectively in laboratory settings. A great deal of time can be wasted by students carrying routine procedures without deep thought about their meaning, or by failing to classify their own thinking and the significance of known literature (Nicol et al., 1994).

There is a growing view that science courses should be encouraging *reflection*, consolidating of understanding and professional awareness. There are two views of professional practice: *the technical rational view* and *the professional artistry view*. The distinction between technical rational knowledge and professional artistry gives rise to two models of professional education and practice: *the competency-based approach* and *the reflective practice approach*. The former values certainties about knowledge, skills and strategies, being able to analyze skills and observe these as visible behavior and setting basic standards against which everything is judged. The latter believes that good work in a profession involves developing knowledge during practice through reflection on practice, which in turn transforms and is transformed by further practice (MacKinon, 1993).

Science educators argue that e-learning can be used to encourage reflection (Schon, 1987, Schank, 2002). The key principles and concepts behind reflection seem to focus on analyzing/interpreting experiences, attending to feelings, engaging/interacting with experience and others, and finding time/space to answer questions raised by the reflective process (Long et al. 1995; Seale, 1997; Shuzhi, 1999; Brockbank and McGill, 1998; Schank, 2002). In the Table 1, it is presented a classification of similarities and differences between e-learning packages that adopt a reflective or a competency-based approach.

Table 1. Similarities and differences between e-learning packages

Reflective approach	**Both approaches**	**Competency-based approach**
• Students can take time out from material and come back to it, how and when they want; • Students are encouraged to attend and record their feelings; • They are also encouraged to use previous experiences.	• Students can interact with the material and others; • Students can interpret and organize ideas and make links between them; • Students can explore and test hypotheses.	• Students using the e-learning package will gain skills and knowledge that can be assessed; • Students are taught to apply theories to practice.

THE STRUCTURE AND FUNCTIONALITY OF CAN

CAN is an e-learning package that allows an on-line educational process. It is concerned with teaching and learning numerical calculus and analysis. In addition to that, CAN provides for apply theoretical knowledge in petroleum engineering.

During the developing of this package, we have taken into account that there are not enough e-learning packages that fulfill the criteria for a reflective practice approach. Therefore, we have been trying to implement as many of them as we have been able to. Throughout the entire development process, we have been guided by the belief that the teaching and learning process can become more efficient if the student is challenged into finding applications of and creating connections between the ideas and facts presented by the e-learning package. Moreover, this could be the start point of a reflective cycle, provided that students use their previous experience, attend to their feelings and take some time out to consider the associations and causal relationships they have made.

CAN has been designed and implemented as a client-server application. Its structure can be seen in the Figure 1. The CAN server resides on the university WEB server called www.upg.ploiesti.ro. It is the one which manipulate the authoring of numerical calculus course, and that manages the physical phenomena database and the log/feedback database. The clients are of two kinds: *student* and *teacher*. Students can use CAN on two levels: *beginner* and *advanced*.

The authoring part of CAN is built using DHTML and Java applets, using a book metaphor. Every numerical method is presented using the same pattern: first some theoretical considerations with respect to the respective method, then practical demonstrations of the way that method works, followed by some exercises (both quizzes and problems to be solved), and finally formal specifications of the main class involved in implementing that method. Every page of the presentation is structured in five areas as it can be seen in Figure 2. Four of them are related with the corresponding level of the interface, and the fifth is the central area where the presentation is actually made. Every level of the interface has a feedback button that allows users to record their feelings and comments into the log/feedback database.

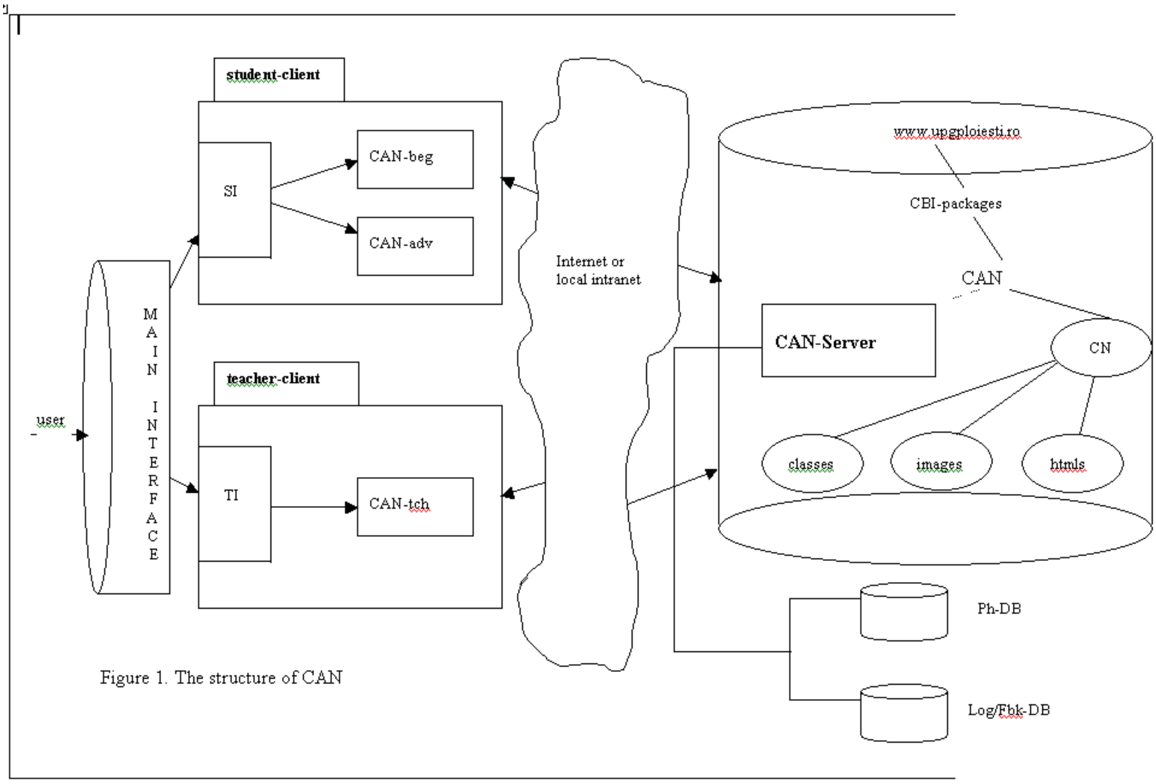

Figure 1. The structure of CAN

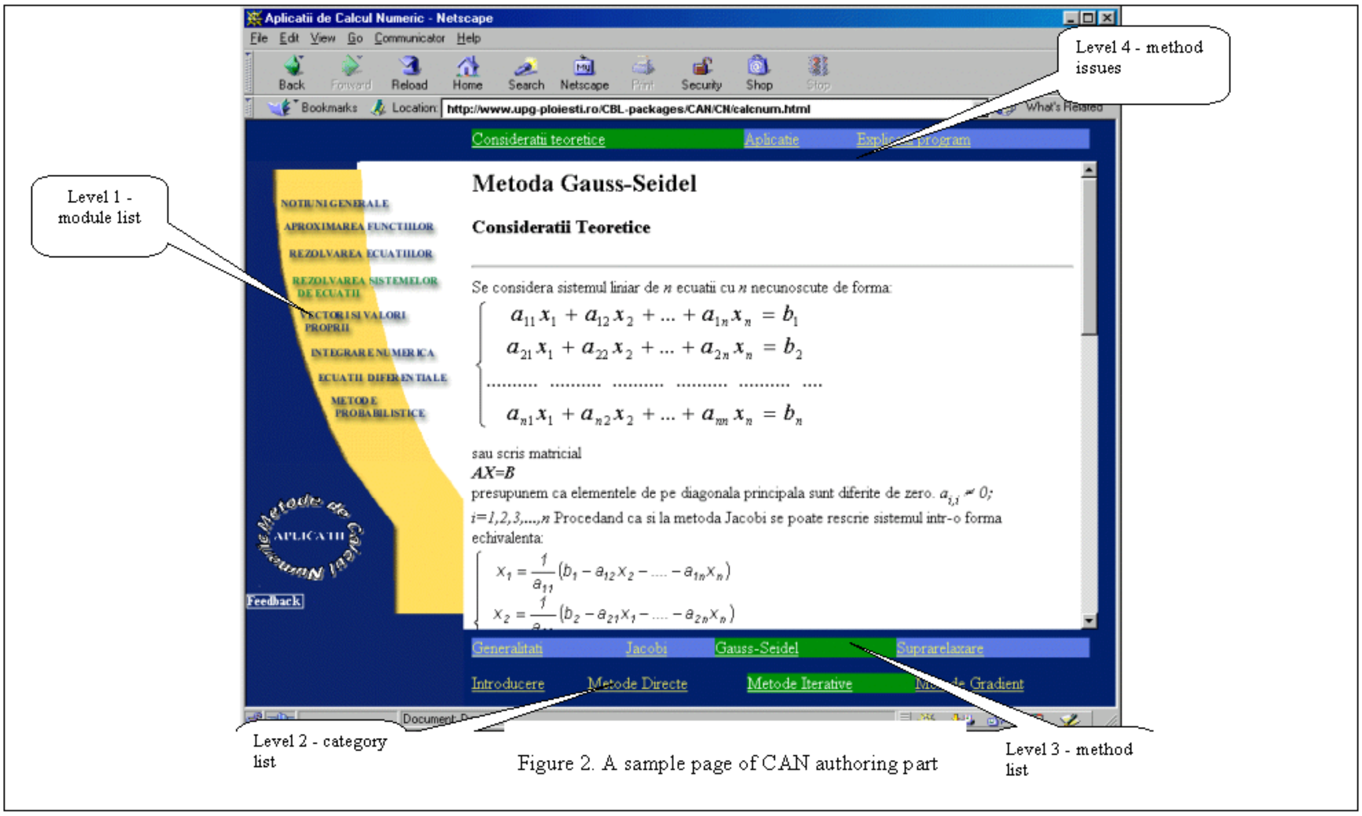

Figure 2. A sample page of CAN authoring part

The *physical phenomena database* stores issues of petroleum engineering that can be solved using numerical methods. Every issue is presented in a <let us remind of> manner. The principal relations here are:

- PhDictionary - having the relation schema (PhID, PhName, DomainName, Sub-domainName, FileURL);
- MethodsPh (PhID, MthID);
- Methods (MthID, MthName, FileURL).

The *log/feedback database* is a storage for log and feedback files. These can be consulted by both teachers and developers of CAN. The main relations here are:

- Registration (UID, FName, LName, Faculty, Goup, Date, Time, UserName, Password) where UID is the user identifier provided by the system, FName/LName are the first, respectively last name of the student (there is also the possibility to fill these fields with *anonymous* in order to provide anonymity), the faculty/group information, the date and the time of the access, and also an username and the corresponding password;
- Tracking (UID, ScreenID, Date, Time);
- ScreenDict (Scr ID, FileURL).

Using the above relations and the capabilities provided by PHP, CAN generates log files.
The feedback information is stored into the Feedback relation having the
scheme: (FbkID, UID, message-text).

In order to built and manipulate these databases we have used PHP 4.3.0 in conjunction with My SQL 4.0.5. They run under Linux RedHat 7.2, using Apache 2.0.42 as the WEB server. The general CAN scheme for information flow is the one presented in Figure 3.

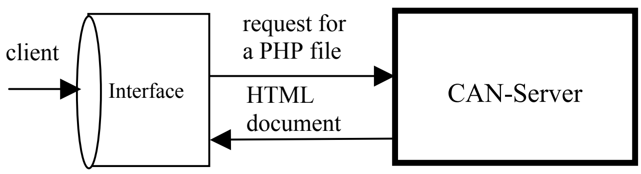

Figure 3. CAN information flow

Students can use CAN in two ways: as beginners or as advanced learners. At beginner level, the student has access only to the authoring part of CAN. Of course, he/she can provide feedback at any level of the presentation. CAN offers solutions to the following numerical calculus issues:

- function approximation by linear/Lagrange/Newton/spline interpolation;
- simple/polynomial regression;
- solving equations using methods like: bisection, cord, tangent, modified Newton, successive substitutions;
- solving equations' systems using direct methods (Gauss, LU factorization), but also stationary iterative (Jacobi, Gauss-Seidel, successive supra-relaxations) and non-stationary iterative methods (decreasing step, conjugated and bi-conjugated gradient);
- eigen vectors and values using following methods: power, Danilewski, Leverierre, Krilov, Jacobi;

- numerical integration (rectangles, Newton-Cotes - trapeziums, Simpson , Gauss);
- solving differential equations utilizing single-step (Euler, Runge-Kutta) or multi-step methods (Adams-Bashforths, Adams-Moulton, Milne);
- solving integrals using statistical methods.

The flow of information for a student client is as follows (Figure 4):

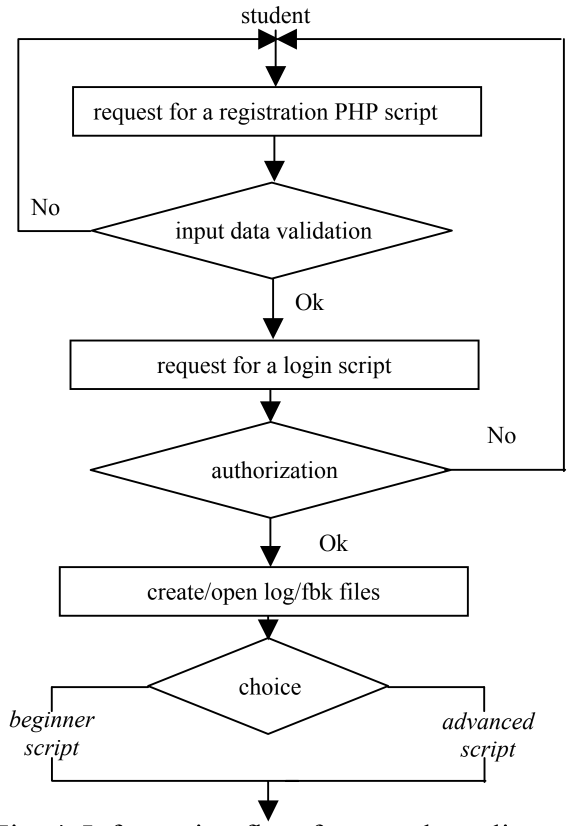

Fig. 4. Information flow for a student client

Advanced students are challenged to use CAN in two ways:

- there is presented an engineering problem and it is suggested a method for solving it – e. g.:

Use linear regression to determine the production forecast, starting from the exploitation history and using decline methods.

The student has the possibility to navigate (by hyperlinks) through the presentation of the mentioned phenomenon. He/she finds there that the exponential decline has the form: $Q=Q_i e^{-at}$, where Q is the oil production rate, Q_i is the initial rate, a stands for the decline coefficient, and t for time. It is given also the production history $\{(t_k, Q_k)/ k=0, 1, ..., n\}$. In order to solve this problem, using the simple regression (y=mx+n), he/she must figure it out that there is necessary the change of variable as following: $lnQ=lnQ_i-at$.

- in this case, it is presented only the problem, without suggesting a method for solving it. The student is supposed to realize himself/herself what is the right method – for instance:

Determine the production forecast, starting from the exploitation history and using decline methods.

Here the student must figure it out that, in order to solve this problem, he/she has to use the simple regression and that the right change of variable is this: $1/Q=1/Q_i+ta/Q_i$.

At both levels, students have the possibility of self-assessment.

The teacher can inspect the content of log/feedback database. He/she can also assess the students, at both levels. There is also the possibility to organize contests between students, the winner being the one who solves faster a given problem.

EVALUATION OF CAN

With large numbers of virtual instructional offerings by universities and corporations, it is imperative to come up with a way to evaluate e-learning applications in a consistent manner. When it comes to outcomes of taking a (e-)course, the real question is: will a student learn something from this (e-)course? Will s/he be able to do something one could not have done before? Keeping this in mind, we have performed an evaluation of CAN using the FREEDOM criteria elaborated by one of the most important authors and developers of e-learning applications (Schank, 2002). Thing to be measured when it comes to efficacy of e-learning are:

Failure – a good (e-)course must enable failures that surprise the student. Failure is the key to learning. One has to work hard to recover when things do not work out the way one expected. That work is what learning is all about.
Reasoning – a good (e-)course encourages practice in reasoning. Education is about teaching people to reason. If reasoning would have been a subject by itself, we could teach people to do it and they would be able to do it. Unfortunately, reasoning in physics is not the same as reasoning in history, in spite of the fact that they do have some things in common. To learn how to reason in our daily lives, we have to practice reasoning in task-specific situations. Being able to handle new issues that come up is the hallmark of intelligence.
Emotionality – a good (e-)course must incite an emotional response in the student. In many ways, emotions are one of the fundamental bases of memory. A well-designed (e-)course must evoke emotional reactions in its students. One such natural emotion can be found in the sense of accomplishment felt by someone who has worked hard to achieve a goal and gotten there. Currently, this emotion is tied to the grade earned and to success at an exam. The issue for (e-)course designers and teachers is to get the emotionality bound to the content in some way.
Exploration – a good (e-)course promotes exploration and enables inquiry. It must be the aim of every (e-)course to provoke students to start to wonder about issues within the framework of the (e-)course. They should be allowed to look around, to go/do where/what they need to in order to satisfy their curiosity. A successful e-learning application enables exploration that make the students interested in knowing more and in finding their ways to get the information they seek.
Doing – a good (e-)course foster practice in doing. Doing is what learning is aimed to. We learn so that we can do, despite of the idea behind most of the schooling today that we learn so that we know. Most (e-)courses leave doing out, being some sort of preparation for do something that never take place. By doing we do not mean here only physical doing, but also mental or social doing. The (e-)course should be about preparing the students to do something, having them doing it, and the having them reflecting upon how well they did it and, finally, preparing them to try again.
Observation – a good (e-)course allows students to see things for themselves. Visual aids have been used by teachers and (e-)course designers for a long time. We all realize how important mental images are. When one tries to recall something usually one tries to picture the scene.
Motivation – a good (e-)course gives motivation. Students have expectations that what the educator tries to teach them will be somehow relevant to his or her life. An important thing to be measured in a (e-)course is the extent to which it motivates the learners to care about their learning. Motivation is an integral part of our memory. If we do not really care about what we are supposed to learn, we have troubles in remembering it in the long term. We cannot trick our memory into being motivated. So, we must try to find out what is the natural motivation of students and weave around it.

Evaluation using FREEDOM criteria

The seven criteria presented in the precedent section are actually quite different from one another. They fall in two classes with respect to the learner: student-dependent (motivation, emotion, failure) or student-independent (doing, reasoning, exploration, observation). This means that mo matter how well done a (e-)course is, it can be inappropriate for a certain student and vice versa. Saying that a criterion is student-independent means that the (e-)course can be assessed by focusing on general issues of appropriateness rather than by measuring how an individual has dealt with it.

The amount of *doing* contained in a (e-)course can be measured as a percentage of the overall (e-)course time. Another key issue in measuring the "doing" in a (e-)course can be mapped to determination of what kind of doing is involved in that (e-)course: doing-driven, doing-centered, or doing-enhanced (Schank, 2002). When we try to measure the *reasoning* the main question is *how often does a student in the (e-)course need to reason things out for oneself?* Other helping inquiries can be: are the problems to be solved by students on their own fundamentally different from the ones they have worked on in the virtual-)class?

Are assignments given for which there are no obvious right answers? Are students asked difficult questions and given the opportunity to give original answers to them and to defend those answers? *Exploration* means to give to possibility to explore a situation by either asking or experiencing, and to get the answers one is looking for. The key issues here are: when a student has a question, can he or she ask it? Are there available many possible responses? Is dialogue encouraged? Is the content interesting enough to provide for inquiry and dialogue? *Observation* deals with images that can be pictures shown or can be views of situations experienced within the (e-)course. Of course, these imaged must relate and be relevant for the (e-)course content.

While is difficult to think about motivation in a (e-)course, as each student is different, we can supply it by building on the natural *motivation* of students. Apart from the fact that a (e-)course is a degree requirement, students could want to learn one particular thing for a variety of reasons: the content is of interest to them, that thing will help them do something they want to do, they are frustrated about it or they think there will be some reward for that. When it comes to *emotion* in a (e-)course the solution can be the connection between emotional situations and learning goals. The most common emotion trigger is the grade, but there are many other human emotions to be exploited: surprise, fear, anger, contempt, envy, frustration, guilt, joy etc. *Failure* is a special kind of surprise. Failures are needed in order to have the learner re-consider one's point of view from time to time. The (e-)course designer have to make failures relevant to what is to be learned.

Using the above metrics, (e-)courses can be graded with respect to their vale as learning experiences. These seven measures are not equally valued. Their relative value is as follows (as percent): 10 for failure, 25 for reasoning, 5 for exploration, 10 for emotion, 25 for doing, 5 for observation, and, finally, 20 for motivation (Schank, 2002). An usual lecture, that includes some real thinking to solve difficult problems, can have the following scorecard: 1 for failure, 10 for reasoning, 1 for exploration, 2 for emotion, 0 for doing (if we score the lecture alone), 1 for observation, and 0 for motivation. The total score is 15 from 100. If we have a look on a flight simulator, its score is 100/100. An ideal e-learning (e-)course should be as close as possible to the maximum score.

We have measured CAN using the FREEDOM criteria and we have come up with the total grade of 58 summing up the following scores:

- *observation*: 2/5. It is quite difficult to use really powerful images in such a (e-)course. Students can have some images included, but those images do not create the learning experience, being mostly a facilitating mean;
- *exploration*: 3/5. The system includes an significant network of interrelated text descriptions and explanations and inquiry feedback;
- *doing*: 15/25. Learners are faced with real problems gradually. They have to deal with them also in a contest atmosphere, which can be a bit of a challenge;

- *reasoning*: 20/25. In order to solve the embedded problems, students must figure out what is the appropriate equation and what is the right change of variable;
- *motivation*: 10/20. Some students are motivated by the fact that they are aware of using these numerical solutions for practical projects in the following years, others are motivated by a better grade and an important part just enjoy to compete with each other;
- *emotion*: 3/10. While numerical calculus is not a very emotional subject, the competition among students can be;
- *failure*: 5/10. In usual experimenting with CAN, failure is personal so it has no much impact on learning. Within the contest it can become more relevant.

Informal feedback

CAN have been used already for 2 years now, by around 300 students from which approximately 265 completed the "Numerical Calculus and its Applications" (e-)course. The average grade for students was 7.7/10. Students have had the possibility to use the system during both normal classes and individual study.

Generally, students liked the idea of online learning, while about 15 percent of them have complained about the fact they have to deal with computer-related issues. They have been very comfortable with the idea of anonymity in self-assessment and seeking help. Students have considered the most appealing feature of CAN, as we have seen from their feedbacks, the possibility to organize contests. We have kept the scores and at the end of each semester, we have given them symbolic prizes.

According with our informal observations, students appear to learn as much or more as in traditional lecture-laboratory based (e-)courses. A significant consequence of using this online (e-)course is the fact that students who have taken this (e-)course tend to solve their term project problems using knowledge achieved during this experience.

Most of the teaching staff members have enjoyed the idea of using an online tool to be released by the routine work and to concentrate on pointing out important specific issues and their future applications. They have used also students' feedback in order to improve their didactic activity. Periodic anonymous self-assessment tests have been very much appreciated as they have provided a quite accurate image of students' progress.

CONCLUSIONS AND FUTURE WORK

People waste huge amounts of time attempting to memorize facts, procedures, and ideas. Such memorization does not have a great impact on behavior and definitely does not translate into learned skills. In addition, many times the expertise is unconscious and it has been obtained in years of practice and experience. The transition from teaching subject content or demonstrating experiments to facilitating reflective dialogue is not a straightforward process. It is difficult for both teachers and learners because of the traditional process of instruction.

Weyer classified leaner goals in using e-learning packages into five types: Tell me, Inform me, Teach me, Guide me, Amuse me, and Challenge me (Weyer, 1988). An important idea to be followed is that any (e-)course can be made interesting by constructing upon natural intrinsic interests and using those interests as a vehicle for presenting the content (which can be less interesting inherently). In practice this means that the content should be connected to learner needs, desires, frustrations and rewards (Schank, 2002). We have built CAN keeping in mind these ideas. Although we have not been using this package for a long time, some improvements in students' results have been seen. We have observed also an increased quality of the engagement for studying both numerical calculus and engineering problems. CAN provides for a learner-centered approach to teaching and for encouraging autonomous learners. It still lack an important feature: promoting of teamwork and collaboration.

We intend to extend CAN in the following directions:

- extending the knowledge embedded in to CAN by adding new modules for solving: equations with partial derivatives, equations' systems (iterative non-stationary methods), eigen vectors and values, function approximation(using numerical series, continuous fractions, or Chebyshev method), Fourier series etc.;
- enriching the physical phenomena base;
- extending the functionality of CAN by adding new modules for advanced learning in other fields like economics;
- adding a module for content-retrieval of information;
- improving the students' feedback module;
- adding features that promote collaboration and teamwork between learners.

We also intend to have a more formal FREEDOM evaluation of CAN, both from students and faculty. We have decided to use this kind of evaluation instead of classical questionnaires because we consider these are rarely sophisticated enough to engage participants in serious reflection and they are often seen as a rather peripheral event to be tackled in a hurry. If we see evaluation as a part of the process of becoming reflective professionals, it needs to take into account features that characterize the (e-)course as a whole and to involve learners in this process.

It is the mission of every (e-)course to teach the students to reason out things for themselves. Of course, there are rules, there are methods of doing things, there are facts, cases and examples to be followed, but mostly there is about figuring out what to do by their own. Learning in a (e-)course really means preparing yourself to go out into the real world and practice what you've learned to do, and this means doing it without help. With the challenging world we live in, this becomes very important for each of us: learners and teachers.

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