Implementation Guidelines and Analysis of Interactive Engineering Courses

Washington Braga & Jaime Tupiassú Pinho de Castro
Associate Professors, Mechanical Engineering Department, PUC - Rio
R. Marquês de São Vicente, 225 - 22453 - Rio de Janeiro, RJ, Brazil
fax number: +55 - 21- 294-9148

Abstract - *This paper discusses some guidelines to the development of interactive engineering courses to be used as productivity tools to enhance student motivation. Although it may be used for distance learning education, the material presented here is aimed to help faculty to better conduct their teaching tasks. Two procedures are presented: one using more heavily web resources and the other using high quality slides, although accessible through the Internet. The material is being used since 1997 by the undergrad students of the Mechanical Engineering Department of PUC-Rio.*

Introduction

It is a common complaint among educators that freshmen usually enter Universities as immature teenagers, not knowing *how to learn*. These students have more than a deficiency in basic training (in math and physics, for instance) to pursue a higher technical education, they also lack the necessary logical reasoning, most needed to scientific and technical careers. This can only be achieved, according to Piaget (e.g. Cromer [1]), after a long process of mental development, that ideally should have happened during primary and secondary levels (or K-12) education.

Many Universities, recognizing that the reality is far from the ideal, are proposing new ways to *motivate* undergraduate students and to teach them how to learn. The challenge is far from a trivial one: most professors educated themselves by the classical listening and reading method, whereas nowadays students are used to harvest blocks of unrelated information from high quality audio-visual media, such as from TV programs, CD-roms or, more recently, from the Internet, where interactivity is the standard feature. Therefore, most contemporary students simply do not have the necessary discipline to read textbooks, and they have a hard time trying to concentrate on traditional lecture-style classes, where only oral (and, sometimes, boring) expositions are the rule.

This paper discusses the motivation for the development of interactive academic material to be used both in the Net and in the classroom, and presents a few general guidelines on the requirements for such courses. A couple of undergrad courses, developed and used at the Mechanical Engineering Department of the Pontifical Catholic University of Rio de Janeiro, PUC - Rio, are analyzed in order to indicate how an interactive course may help to educate future engineers.

Motivation For An Interactive Course

As administrators have learned by now, there is no limit on the necessary money one can spent buying computers, hardware and software, connecting them either on a local area network or to the Internet, and in training, lots of training (even though, this is many times the neglected part, in order to decrease the bill). To many, money spent this way is somewhat wasted, as no significant improvement on *education* has so far been noted. Therefore, they argue that academic productivity must be improved prior to further investments, indicating a poor perception on the present importance of computer literacy (or the ability to manipulate, manage and understand computers effectively, Jewell et al [2]). There are at least four facts that must be understood today:

Fact 1: Internet is here to stay

The almost unlimited local access to information exchange in all forms, and the fast and cheap both synchronous and asynchronous communication features, are the main reasons for the huge Internet success. Even non specifically trained people easily perceive its potential, after only a few hours connected to the Net. It is not difficult to observe how its concept has spread throughout the society, changing communication habits, promoting new business opportunities, and even changing the way people think and act. Certainly, it has some serious problems, such as spamming (electronic junk mail), cultural threads (insofar language is plain English, most of it), pornography, racism, not to mention possible globalwide censorship. Should we give up Internet potentials due to those? Important new technologies are never neutral [3,4], their mere existence may result in significant modifications on the environment they are to be used. See, for instance, the transformations that the whole society went through after the invention of the press or of the steam engine. Clearly, one should always be aware that there are potentials both for the good and for the harm (e.g. Moran [5]), however no one can simply ignore an important technological breakthrough.

Fact 2: A new technology may interact symbiotically with a traditional one

As put by Hodas [4], schools may be considered a technology, provided one understands that they use a body of knowledge towards an assigned goal, in this case, education. In them, teachers, administrators and students are blended with blackboard, chalk, books, computers, labs and all other equipment, in other to transfer knowledge from educators to the students.

Very likely many lengthy discussions were conducted in the past, when books started to be used in classrooms after the invention of the press, as oral presentations by Readers were until that time the only option to obtain an education. These days, one should understand that Internet linked computers is just another technological tool that can be helpful in the learning process. In this sense, it seems natural the resistance some educators (and others) offer, as they will need to learn a new technology.

Fact 3: Dependence on information technology

There are, most certain, many people that still complain on the money spent on the acquisition of computers, as there are always many other necessities. The real problem is related to the maintenance costs (which includes periodic software and hardware upgrades, and training) that are many times higher than the cost of the initial equipment. For example, Institutions have too often to upgrade or replace "old" computers, as these do not perform efficiently new versions of the software used. In consequence, administrators fear (with a good reason) to become economically dependent on computer investments that are certainly endless. However, since no one can simply give up computers, the real objective is to use them to maximize the profit.

It seems reasonable to argue that only educators may solve this problem. It is already time to show positive results indicating the enhancements on academic productivity obtained through the usage of information technology (Massy and Zemsky [6]). Perhaps, the goal could be set to a more serious commitment to the enhancement of the teaching and learning processes.

Fact 4: Graduation requirements

If globalization, collaborative work, lack of jobs and continuing education are keywords these days, academic Institutions should start paying more attention to the kind of education they are offering their students. In the recent past, professors in the classroom (i.e., at the central stage) had the power to educate their students in a body of knowledge they were supposed to master completely. However, since the technology obsolescence is occurring at an ever increasing rate, the situation has changed significantly. Moreover, in Brazil, and probably in other countries too, it has been common to note that recent graduated engineers find more jobs at non-engineering positions.

Therefore, instead of giving only the traditional technical subjects, it should be wise to start offering also a more basic although wide spread education for the future engineers. The students primarily should be taught on how to learn by themselves, and then to use information technology, to find good information, to transform information in knowledge, and also on how to develop good communication skills and to work collaboratively. Since this task must be achieved without neglecting the basic technical training and without increasing the time to graduation, it can only be fulfilled by modifying the way the traditional courses are taught.

Interactive Courses Methodology

The domain upon a knowledge body requires three steps: (i) *information*, to overview the subject, (ii) *study*, to understand its details, and (iii) *practice*, to use it profitably. Knowledge cannot be transferred, it must be conquered: the learning process is a personal task, however it is easier and faster in group than alone. This explain the unquestionable success of the traditional school model, which includes in one hand professors, students, physical facilities and a studying ambient, and in the other discipline and a collection system: well defined curricula, specific schedules and quizzes.

A good teacher must be clear, dominate his subject, be able to orderly explain the basics and the important details of the matter, and to exemplify how it can be used. But he also must perceive how the class is following the ideas, to adapt the explanation to maximize the transmission rate. A good formal course must have a timetable and a progressive and well defined program, covering the matter to an appropriate depth and presenting difficult quizzes, to stimulate the study. The professor-student tuning, the interaction between the students, the lab practices, the homework, the discipline and the evaluation system are the main advantages of a classical school.

However, at the academic level graduation time is a certainly a limiting factor, as the corresponding costs, that are already very high, constitute a burden to the students and to their paying families. Due to the remedial classes for weak freshmen, and to the ever increasing amount of information students must grasp, graduation day may be postponed for years, becoming almost impossible to be achieved in a reasonable time span. But, as it can be learn from the businessmen, the adequate management of information may reduce costs and increase product variety.

Many people (e.g. [7]) have been promoting distance education as an efficient instruction method, provided good student-to-student interaction and teacher-to-student feedback are used. Most distance education programs today use Internet as its learning media, due to its powerful information technology resources and potential for interactivity, through the combination of services such as web pages and email. As it may be expected, one of the complains made is that the distance learning classes lack the teacher's physical presence, and the other advantages of the classical school. However, there is no doubt that both approaches can be used at the same time.

At the Mechanical Engineering Department of PUC-Rio, it was decided to combine web-based training with a standard lecture-style course. A series of web pages were developed for an undergraduate heat transfer course, which include the basic theory, many solved examples, proposed exercises, motivation questions, lengthy frequently asked questions (faq's), and others, that may be projected on a screen through a standard data-show equipment during the class. From the home page (**Error! Bookmark not defined.**), Internet services such as email, ftp, Usenet news and chat may be accessed. Usage of movies and radio (Internet Radio) are still quite limited, mainly due to poor telecommunications links.

Once a week, off-hours special tutoring were offered by chat conferencing, in which extra credit exercises were assigned. E-mail type of service (including Usenet news and a discussion list) were used to virtual interaction between teacher, tutor and students.

In order to promote greater interaction among students, at least two open-ended projects were assigned per term. To develop them, students were supposed to look for the needed data. For the next term, 6 simpler (not necessarily easier) projects will be assigned, as it was noted that students are easily motivated to this type of work. It was observed that shorter projects allow higher interaction among students, as the assigned time is shorter, resulting in greater achievements towards the understanding of the physics involved. The projects involved many experiments from daily life, such as observing how a refrigerator works, and the basic features from the heat transfer course, such as boiling heat transfer involving critical heat flux, and were due within 3 weeks at most. Many of the topics were not discussed at classroom prior to the assignment and were proposed to increase students' awareness of engineering problems.

High interactivity levels were achieved through the usage of downloaded software (e.g., [8]), spreadsheets, Java programming, animation, etc. Intensive use of such software coupled to technical discussions on solved problems transformed the classroom teaching and learning on an interactive processes, a desirable feature, following Bostian [9].

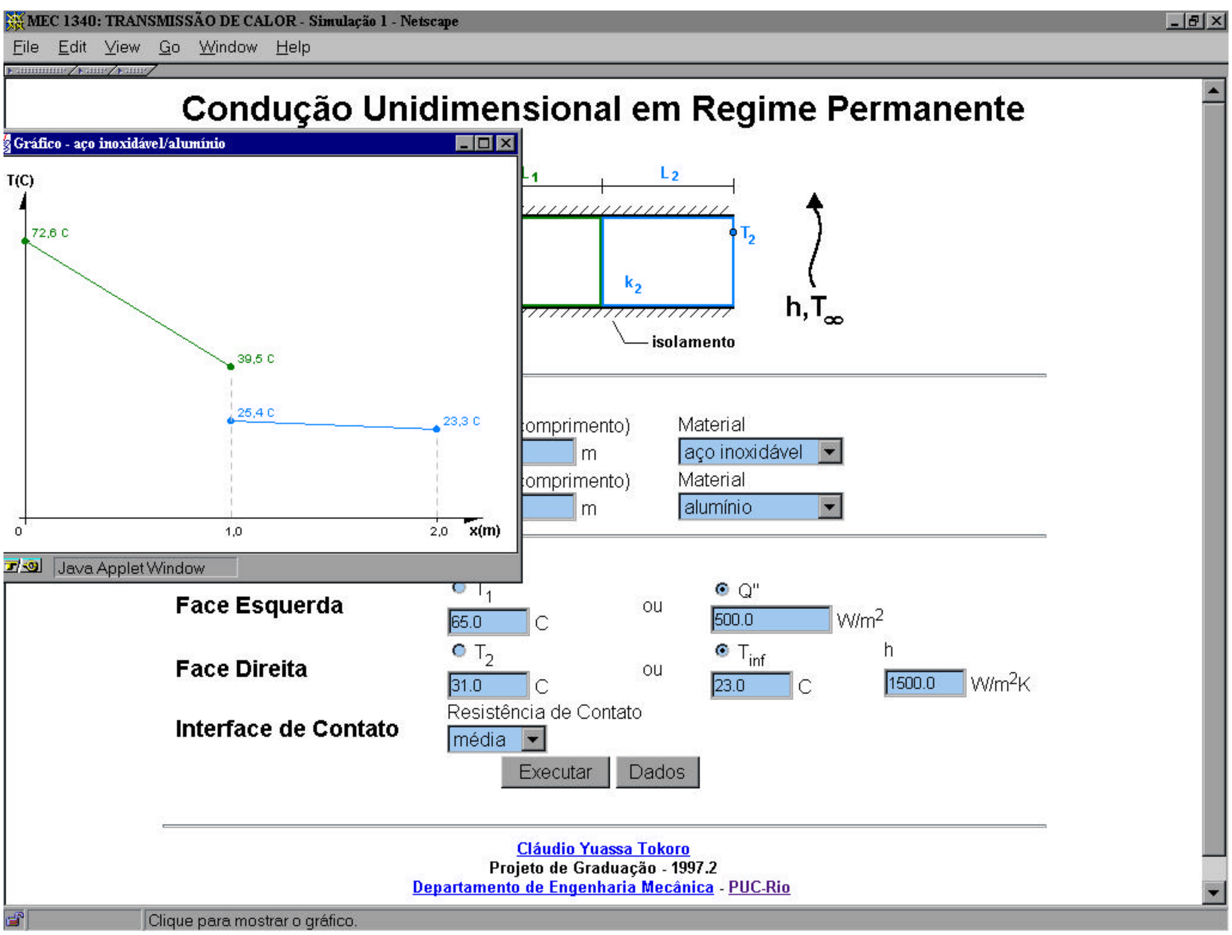


Figure 1. Java Interface, showing user selected thermal boundary conditions, contact resistance and temperature profiles for two slabs made of different materials.

Figure 1 shows an example of one of the interfaces, developed using Java, in which students may visualize the effects of thermal boundary conditions and the thermal contact resistance on the temperature profiles of two slabs of variable length and specifications.

In another course, Mechanical Behavior of Materials (**Error! Bookmark not defined.**), a different approach was used. To test how a teacher with no previous training in the Internet environment could profitably use some of its simpler facilities, the course was planned to rely on the web resources to a lesser degree. Therefore, the idea was to develop a series of about 300 high quality slides to illustrate and complement the oral classes, and to serve as an extended summary of the subject. This summary by no means is supposed to substitute the textbook, it is a supplementary teaching aid.

In the classes where the subject is more of an informative nature, such as those where a revision on engineering materials is made, the visual appeal of the slides permit a much higher transfer rate. In the formative classes, such as those on fracture and fatigue, first a series of slides showing the effects of the failure mechanism is presented, them the dimensioning theory is developed in the blackboard by the oral (traditional) method, and finally the matter is summarized using the slides.

It is important to note that these slides do not work as improved transparencies. On the contrary, they are a dynamic teaching material, which can be easily modified every time a student rises a pertinent doubt. The use of a computer and a data show to present this material during the classes is much more versatile than a simple slide projector. It permits that complex design examples which require non trivial theory and calculations (fatigue dimensioning under complex load, e.g.) be presented in the classroom environment. In figure 2, an example of such a problem is illustrated. Moreover, a specifically developed software, **ViDa 98**, is used to make the required calculations.

This very powerful program, described elsewhere [11], was developed to automatize all the methods traditionally used in mechanical design to calculate the fatigue damage caused by complex loading: SN, IIW (for welded structures) and εN to predict crack initiation, and da/dN for studying uni and bi-dimensional crack propagation, based on Fracture Mechanics concepts. It has several intelligent data banks, two rain-flow counters and a race-track filter, corrected histeresys loops generator, automatic adjustment of experimental data, an equation interpreter, and a number of other similar features, all in a friendly graphical interface which runs in a Windows environment. Moreover, its damage models include various non-trivial innovations to improve the calculation speed and accuracy.

The slides are available to the students on the Net, as are the detailed course program, proposed reading material from the textbook and other pertinent references, the quizzes solutions and solved examples. The students are stimulated to use the e-mail to ask questions, both on the class and on the laboratory material.

Analysis

It should be made clear that the proposed course's design is instructor's dependent, in the sense that it is understood that no physical reasoning and experience may be transferred by a handful of bites, no matter how colorful they may be. That is, it is not expected that any software, sophisticated as it might be, is going to replace a good instructor, with experience obtained from research and engineering practice. It is rather understood that the central instructor's role on the educational environment may be enhanced, not substituted, through the usage of information technology, provided it is conducted by someone interested and capable of doing so.

Nor the teaching aids are supposed to replace textbooks. As said above, education is more than information, it requires study and practice. There is still no way one can study without the systematic reading of good books. The objective of most virtual material and the assigned projects is to allow greater interactivity among students and instructor, at any needed time, using any available media, and to help immature undergraduates to transit from the information to the study level.

The development of instructional material is very time consuming and may only be justified provided there is any kind of academic improvement. In both the Heat Transfer and the Mechanical Behavior of Materials courses, the instructors had to spent most of their time in this task.

At this stage, unfortunately, no careful conducted investigation on the learning benefits of this kind of effort to develop such instructional material was performed, nor with the materials developed at ME Department nor elsewhere, to the best of the authors' knowledge. There are certainly many technical documents (e.g. Crain [10]) that mention great improvements on students' recall provided multimedia material is used. Consequently, it seems reasonable to state that increasing the student-instructor interaction through the combination of lectures and usage of recorded interactive material, available through the Internet or else, should have a positive effect on students understanding.

At this point, however, at least a qualitative analysis can be made. In the present case, the students gave high remarks to the Heat Transfer and to the Mechanical Behavior of Materials courses. The elimination of the troublesome task of copying what has been written on the blackboard, the easy replacement of missed classes, greater availability of teacher and tutor, etc, were all appreciated. Particularly, the order and discipline, which are some of the most important advantages of the classical school model, were significantly improved.

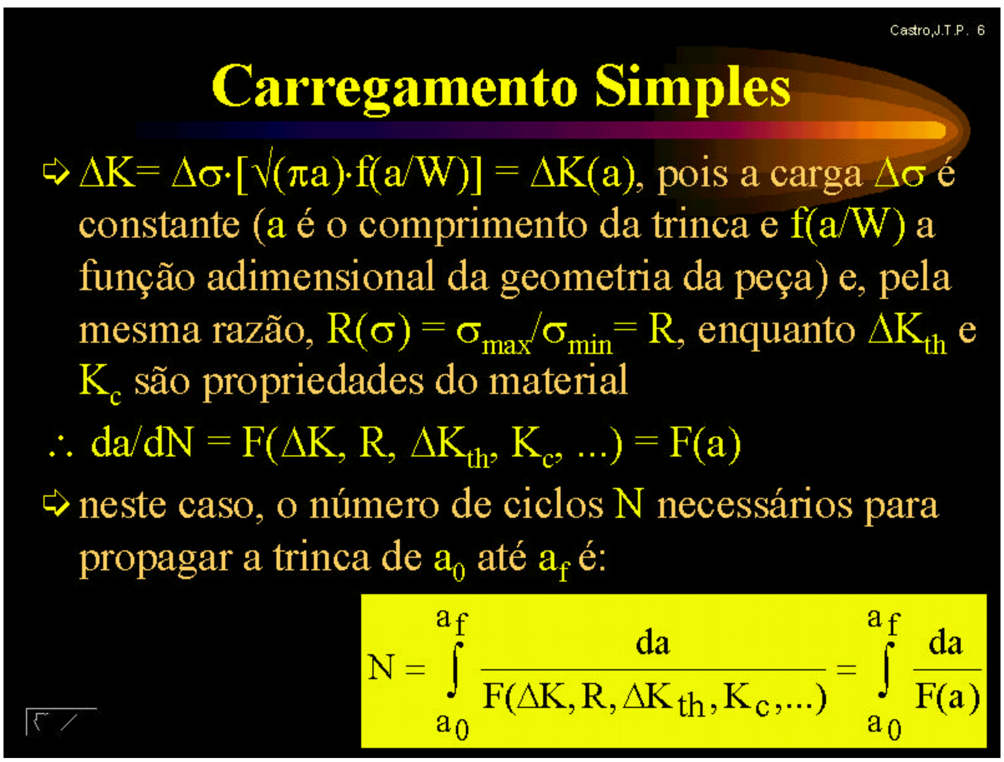
The well-organized material displayed in class helped the students to easier follow the oral presentations, as their time could be used to participate in the technical discussions on the taught material, always stimulated. Due to this significant reduction on the amount of time effectively spent on non-intelectual tasks, it was possible to allow the students to preview the material prior to the teacher's explanation, or to let them work on the development of their own projects.

An other benefit was the new potential to present to the students the solution of some real-life (complex) problems in the classroom environment. Even thought these problems are well above the quizzes level, they do serve as motivation for further studies.

On the other hand, it has been noted that efforts should now be directed in order to increase interactivity with the students, using Java programming or similar web-based materials, as the interaction achieved was very interesting, notwithstanding its simplicity. As they lack the scientific thinking, perhaps not yet fully understood at their age, they need to visualize the physical laws involved, turning them "real", hopefully in an inexpensive way. Simple simulation material seems to work fine on such matters.

Conclusions

This paper addressed some arguments used to justify, at this stage, the investments necessary to make interactive courses. Instead of using Information Technology resources to produce distance learning courses, it was decided to use them to develop a mixed environment to allow in a classroom the use of Internet facilities. These come whether from web pages or from other interactivity resources, such as Usenet news, Java software, etc. To further motivate students, collaborative projects were assigned, allowing them to work in some engineering problems, as soon as they master the basic physical arguments. It seems that the availability of well designed interactive instructional material, short length projects and capable educators may help students to overcome their current deficiencies.



Propagação de Trincas por Fadiga

- quase sempre perpendicular à máxima tensão trativa
  - ∴ o modo I é de longe o mais importante na prática
- da/dN é controlada por $\Delta K = \Delta\sigma\cdot[\sqrt{(\pi a)}\cdot f(a/W)]$
- quando o carregamento é simples, "basta" integrar a curva da/dN usando o valor do ΔK solicitante
- esta tarefa pode ser operacionalmente complicada, mas é conceitualmente simples
- *no* **ViDa 98** *pode-se trabalhar com qualquer regra da/dN e com qualquer função para* ΔK

- N em geral tem que ser calculado numericamente, mas como, apesar de complexa, F(a) é uma função suave de a, a discretização da integral não precisa ser feita a incrementos muito pequenos
- e.g., para prever quantos ciclos são necessários para propagar uma trinca central de $2a_0$ até $2a_f$ numa tripa, usando a regra 4P-2 e o método dos degraus:

$$\Delta K = \Delta\sigma\cdot\sqrt{\pi a}\cdot\left[1-0.025\left(\frac{a}{w}\right)^2+0.06\left(\frac{a}{w}\right)^4\right]\cdot\sqrt{\sec\frac{\pi a}{2w}} = \Delta K(a)$$

$$\frac{da}{dN} = A_2\cdot\frac{[\Delta K-\Delta K_{th}\cdot(1-\alpha R)]^{m_2}}{[K_c-\Delta K/(1-R)]^{p_2}} = F(\Delta K, R, \Delta K_{th}, K_c, \alpha) = F(a)$$

$$\therefore N = \int_{a_0}^{a_f}\frac{da}{F(a)} \approx \frac{a_1-a_0}{F(a_0)}+\frac{a_2-a_1}{F(a_1)}+\ldots+\frac{a_{i+1}-a_i}{F(a_i)}+\ldots+\frac{a_f-a_{f-1}}{F(a_{f-1})}$$

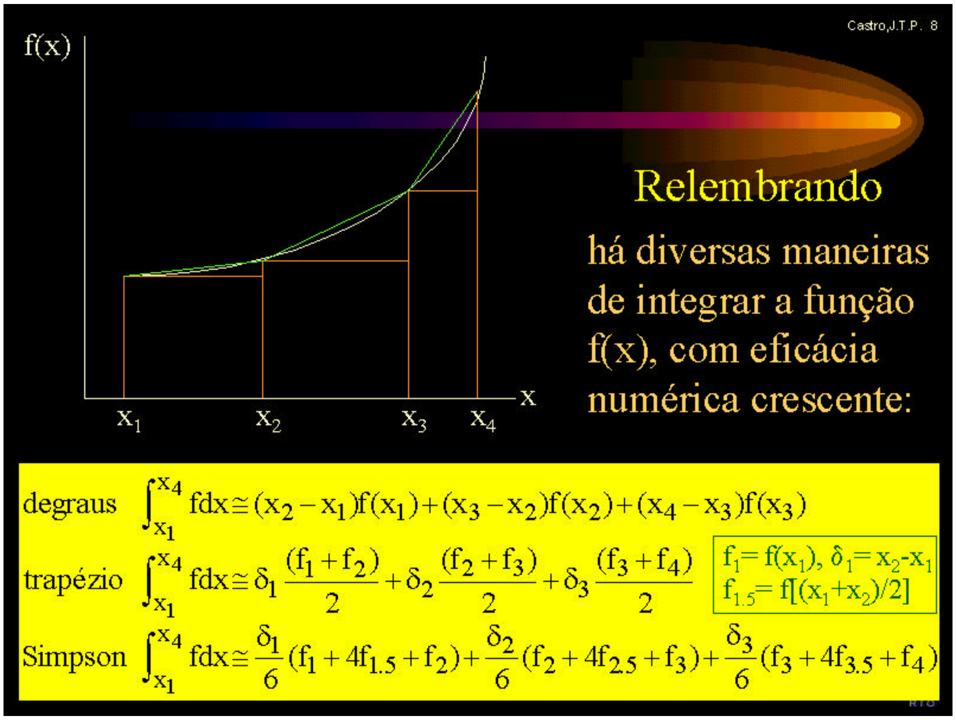


Figure 2: Slides used to teach fatigue crack propagation using complex rules, which require numerical integration. Since the students normally do not remember the integration procedures, the visual information is an efficient teaching aid.

References

1) Cromer, A, "Uncommon sense - the heretical nature of science", 1997, Portuguese edition, Faculdade da Cidade Editora;

2) Jewell, L. & Manning, M., "Bringing Teachers and Technology Together in the Classroom: An Overview", available in the Internet at the URL: **Error! Bookmark not defined.**, 1997;

3) Postman, N., "Technopoly - The Surrender of Culture to Technology", 1992, A.A Knopf, Inc.;

4) Hodas, S., "Technology Refusal and The Organizational Culture of Schools", v.1.3, 1993, available by email to hhll@u.washington.edu, 1993;

5) Morin, E., Bocchi G. & Ceruti, M., "Un Nouveau Commencement", Portuguese edition, Editorial Notícias, Portugal, 1991;

6) Massy, W.F. & Zemsky, R., "Using Information Technology to Enhance Academic Productivity", **Error! Bookmark not defined.**, 1996;

7) "Is Distance Education Effective?", extracted from "Distance Education at a Glance", developed by University of Idaho, Engineering Outreach staff, available at **Error! Bookmark not defined.**;

8) Interactive Heat Transfer, available in Incropera, F.P. and DeWitt, D.P., "Fundamentals of Heat and Mass Transfer", 4/e, John Wiley & Sons, 1997.

9) Bostian, W., "The Mechanics of Effective Classroom Teaching", Engineering Education, January/February, 1991;

10) Crain, L., "Effects of Instructional Media on Immediate and Long Term Recall", Interpersonal Computing and Technology Journal, vol. 2, no. 2, pp. 19-27, 1994;

11) Meggiolaro, M.A. & Castro, J.T.P. "ViDa 96 - Visual Damagemeter to Automize the Fatigue Design under Complex Loading", in portuguese, submitted to the Journal of the Brazilian Society of Mechanical Sciences.