EXPERIMENTAL TOOLS FOR THE TEACHING OF TECHNICAL GRAPHICS AND IMPROVING VISUALIZATION

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Abstract. This paper presents an updated evaluation of an experience of applying computer graphics, virtual reality and Internet resources in the teaching of technical graphics at the University of Brasilia, Brazil. It differs from a previous paper (Pratini, 2004) for the addition of an overview of the course, the context and the new teaching methodology. It is an extended, more detailed paper, which includes examples, and closes with some results of surveys on the didactic material and the methodology. Our motivation for this experiment is the fact that most of the students have a lack of previous knowledge on the basis of drawings, resulting difficulties in both understanding and visualizing technical drawings. In this experiment, we introduced VRML 3D modeling in addition to CAD and regular pencil-and-paper drawings study and practice. To support the learning of this broad knowledge not present in the technical graphics bibliography, we first provided a website with animations and virtual reality resources. Since 2003 we are providing a CD-ROM containing all the former website material which is updated each semester. At the present time, the CD-ROM contains almost all the needed didactic material and software for the one semester technical graphics course. This experience was intended to improve and to support learning in a way that motivates the students, young people who are used to play video and computer games. Classes, website and CD-ROM material were conceived to take advantage of computers´ interactivity and animated resources. The use of computers´ technology and new media to support the learning resulted a new methodology and several new unanswered questions.

1. Introduction

The origin of our experiments on 3D computer graphics as a tool to develop visualization in a Descriptive Geometry course comes from the early 90´s.

At that time, we identified some difficulties of our students related to the understanding of the projection process, the reading of technical drawings and the establishing of the relation between their own view of a real object and its views in orthogonal projections.

It is important to point out that, for more then 90% of the undergraduate students in Brazil, the courses of Descriptive Geometry or Technical Drawing are their first contact with formal drawings. These students, attending the first semesters of an undergraduate course, have little or none knowledge about projections, perspectives or, in many cases, even the basics of drawings.

In the late 80´s, some researchers in Brazil were proposing a different method of teaching Descriptive Geometry which we adopted: instead of the traditional point-line-plane sequence of teaching, the comprehension at first on how a solid object is orthographically projected over the planes allowed to a better understanding on how its vertices (points), edges (lines) and faces (planes) appeared as orthogonal projections.

Following this method, some steps of the process became easier for the students´ understanding. However, some students still had visualization problems, such as a lapse regarding the understanding of the relation between the representation of an object - its projections - and the many possible views of the object itself.

After making drawings based on physical solid models, the next logical step to make it easier and to assist on the understanding seemed to be the introduction, in the course, of the emergent computers´ 3D modeling technology. At that time, a simple and easy 3D modeling software available in our incipient computer lab allowed the students to construct and to get better visualization of the same objects they had drawn and studied before and also to model, understand and draw much more complex objects (Fig.1).

Figure 1. Three 3D models from 1991´s first semester Descriptive Geometry students

This experiment was held from 1991 to 1993 and showed that virtual 3D models could be a future way to replace orthographic views, which were identified as a large part of the visualization problem.

A few years later, the courses of Descriptive Geometry and Technical Drawings were merged into a one-semester course. Returning to the teaching

of this new discipline, we followed the trend of using CAD instead of pencil-and-paper drawing in class. However, after one semester using computers to draw, it became clear that the students were getting much more involved with the software, its commands and resources than with the understanding of the principles of technical drawings and visualization of the drawn objects. They were making drawings more based in the resources of the software than in the techniques and rules of representation.

From that time on, we discouraged the use of CAD, returned to the practice of hand sketching and drawing, and started to explore other resources and new technologies. Since 2000, we introduced the use of very simple and didactic photogrametry and VRML (Virtual Reality Modeling Language) modeling tools to construct and visualize complex 3D models and to do exercises in parallel to pencil-and-paper drawing, as we did in the former Descriptive Geometry classes.

It is important to notice that, for us, any software is always just an instrument for achieving the desired results, i.e. representation and better visualization of the objects. The tool should be as simple and easy as possible, hence the students can focus on the process of construction and visualization and NOT on the learning of software commands. This is the reason for not using software such as 3D Studio or other complex 3D modelers in these first semester courses.

From the second semester of 2000, we took the experience of visualization and interactivity to the Internet, providing to the students a website designed with animation and virtual reality resources, avoiding the usual textbook metaphor (Fig. 2 and 3).

Figures 2 and 3. The course's homepage started as a newsletter format. The image on the right (Figure 3) is a screenshot of the current homepage.

Since 2003, we are providing a CD-ROM containing all the former website material which is updated each semester. At the present time, the CD-ROM contains almost all the needed didactic material and software for the one semester technical graphics course. The intention of all this experience is to improve and to support the learning in a way that motivates the students, young people, who are used to play video and computer games.

Classes, website and CD-ROM were conceived to take advantage of computers´ interactivity and animated resources.

2. The context and the teaching methodology

The use of computers´ technology and new media to support the learning of technical graphics resulted a new methodology for the course.

This methodology has been developed and applied from 2001 in the Technical Drawing courses at the Department of Civil Engineering of the University of Brasilia, Brazil.

This Department is responsible for five classes in each semester with the attendance of 140 undergraduate students.

Depending on the students course, Technical Drawing is a first or second semester discipline. In both cases, the students come from High School with some skill on computers [1] but little or none knowledge of drawings, representation and their instruments.

The methodology for these classes is a combination of theory and practice both in computer lab and in atelier as briefly described below:

- Technical Graphics is a four credits course, with two classes a week of two hours each, 31 classes a semester.
- The current course's contents involves a broad knowledge - basics of Descriptive Geometry, technical drawing, computer graphics, 3D modeling and VRML language condensed in just one semester - hence the learning is based on the classes and on a supporting CD-ROM, which brings together almost all the needed knowledge and software.
- The first class of each week is carried out in computer lab and the second class in a traditional drawing atelier. The theory is taught in the computer lab classes, always illustrated with the CD-ROM material – animations, 3D interactive models, step-by-step presentations, tutorials, etc. The hand drawing practice – typically orthographic views and perspectives of objects - takes place in the atelier with exercises related to the previous theory.
- After the first month of the semester, we introduce the basis of 3D computer graphics and VRML language in lab classes.
- The following step is to review the same drawings performed manually in atelier, transposing them to computer graphics and 3D models. From this point on, drawings are translated to 3D models and vice-versa.
- We continue the semester performing 3D VRML modeling in parallel with hand drawing exercises. At the same time that the plan drawing is taught, for example, the students are asked to model a simple furnished space.

[1] All of the students have computers at home.

- This model is first described in a natural language algorithm and then written in VRML language. We do not use a 3D modeler at this moment for the intention is to exercise the students´ capacity of visualizing and describing the space. To better accomplish this, the CD-ROM provides a large library of VRML 3D objects; the students just need to model the space and put the scaled objects together in the correct place (Fig.4).

Figure 4. VRML 3D model constructed by a student in 2004. The chairs, tables and trashcan are free models from Internet. Everything else was modeled directly in VRML language.

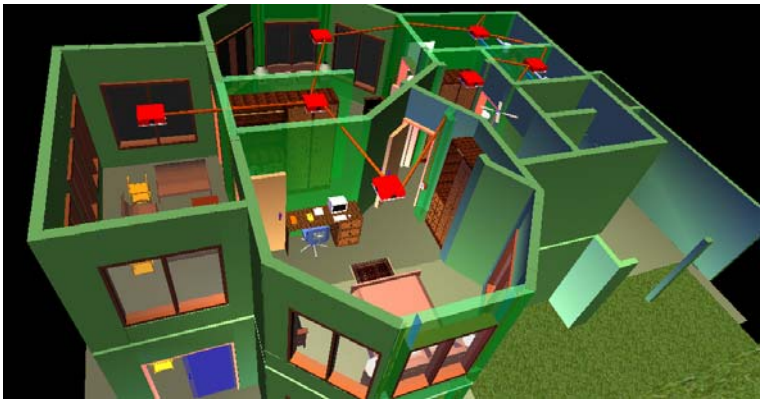

Figure 5. At the end of the semester, students are asked to construct a VRML 3D model of a house or apartment which includes positioning the furniture, lamps and points of electricity needed for every function. The image shows one of the models from 2005.

- At the end of the semester, students are asked to use all the acquired knowledge – hand drawing of plans, sections, elevations, perspectives, techniques and rules, 3D modeling, etc. The theme is a copy of the plans of a simple house or apartment. The project is developed and detailed with paper-and-pencil technical drawings and perspectives in atelier and finally modeled in a very simple 3D modeler (Fig. 5).

3. The website conception and development

The first guidelines for the construction of a local, learning supporting website, came in 1998 from two issues that we identified in some so-called distance learning courses all over the world.

- First, because web design did not develop its own language, designers were using the textbook metaphor in education. Websites composed only by text and figures were called distance-learning courses, although, in most cases, they were simply chapters of books or notes of classes in a web page format. These e-texts had no other attractive than a valuable spreading of the information over Internet. Typically, the destiny of these texts on screen was the return to the printed format. An informal inquire among the students of the University of Brasilia showed that most of them, even today, print all the contents of a textual website in order to read it later.
- Second, although the technology allowed interactivity and much more, it was frequent to see poorly designed webpages using easy special effects or animations just to mask their bad concepts, and not to contribute for a better contents.

These two issues clearly pointed out one solid way to construct a website, if we wanted it different and better than the others we were used to see:

- If there was such a remarkable superiority of the printed text over the electronic one, we should avoid, as much as possible, text-only contents. If the contents of a local website needed too much text, it would be better and require less effort to provide paper copies directly to the students.
- If the technology on the Internet allowed to do animations and to be interactive, we should take advantage of these facts for our courses contents, which were, in nature, essentially visual.

These two guidelines oriented the construction of the website. The first version was more like a newsletter. In this early website, we used to put proposals of exercises and their solutions, news, announcements and tests solutions. Since the beginning, either VRML interactive models or a few animations accompanied all the exercises and the short theoretical explanations (Fig. 6).

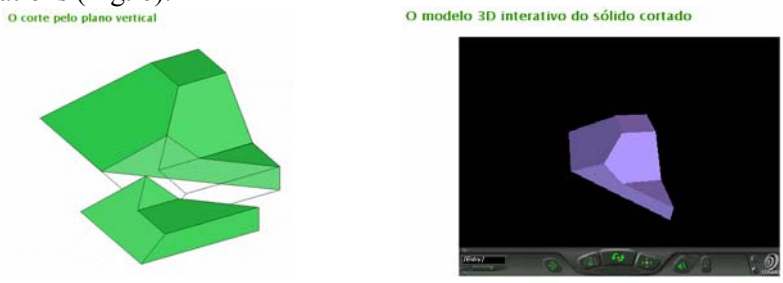

Figure 6. The website or CD-ROM exercises are always illustrated with 3D VRML models and, sometimes, with 2D or 3D animations – or both.

As the website evolved, new interactive and animated material has been developed and added to compose a menu of pages which included the curriculum, exercises, past tests solutions, theoretical explanations, news, rules and standards, links, free software, etc. (Fig. 7).

All this material was conceived to be an additional, supporting tool, in a way that the students could reinforce their learning outside classroom. It was not intended to be a truly courseware as this would demand much more resources, such as interdisciplinary teamwork or online feedback.

4. Some issues on the experience over Internet

A number of researchers in and outside Brazil are working with computers, animations, virtual reality and Internet resources in order to teach, to solve or to minimize problems related to the technical graphics - Descriptive Geometry included in this body of disciplines. We all seem to share similar questions: how to improve on the assistance of the visualization's development; what is the most efficient media to disseminate the knowledge; what kind of technology to be used; how to use the available technologies; how to motivate the students to study taking advantage of the provided material, software, method or technology; etc.?

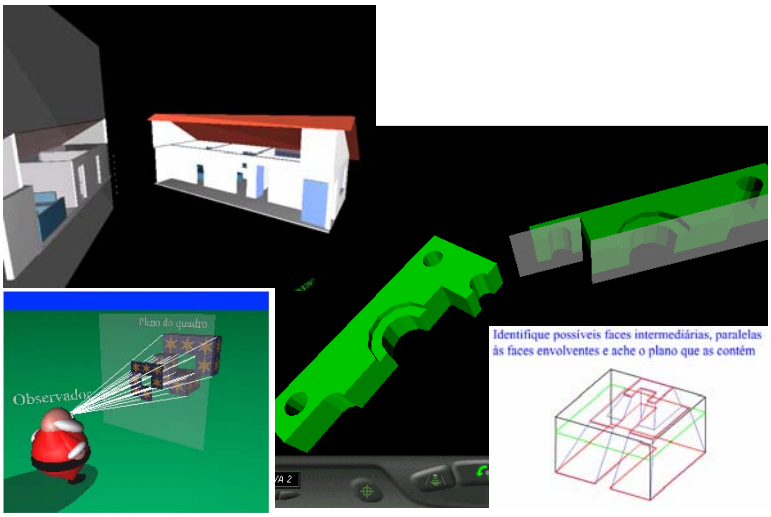

Figure 7. Tests and theoretical contents are also illustrated with 2D or 3D interactive, animated material.

From some previous experience, we were reasonably sure that the students would be stimulated to access a website and to use the interactive

resources provided in its pages. For two years, we have provided to them a free access website full of information, 3D interactive models and animations, library of problems and tests, etc. in addition to the classes. The monitoring of the site showed that there were a large number of accesses.

But something was wrong. The feedback of the tests did not show such an improvement in the students' visualization or knowledge.

After all, we realized that the students were not really using the site in its full potential. An informal inquire among the students identified the following facts:

- Although recognizing that the website material was very helpful and of easy understanding, few students were accessing the site to reinforce class contents; many were considering that they had seen and learned enough when the contents and the material of the site - animations, models, etc. - was shown and explained in class; these students would only access the site again the day before a test;
- Many students were actually accessing the site but were NOT staying connected enough time to use and explore the provided resources;
- Most of the students were not exploring the site and searching for information as they used to do in recreational ones;
- Many students alleged problems in their connection to the Internet as a reason to not access the library of exercises and tests;
- Most of the students have tried to print the contents of the site. However, there were many 2D and 3D models and animations that were not possible to print. Consequently, the students asked for printed materials;
- Many students were satisfied in just reading the proposal of a problem and then accessing and visualizing its solution, which included VRML 3D models. They were not trying to solve the problem by themselves.

Once again, there was an indication of the need of printed material even among young people used to stay in front of a computer's screen for hours. Maybe the problem is that they cannot bring with them a connected computer all around the campus for taking a look any time, any place.

Furthermore, there was a connection problem: at that time, the students used dial-up connection to access Internet from home. Staying connected for long time could represent an undesirable expense. This might partially explain why many of them did not dedicate enough of their time to explore the site.

5. Changing to a new media

From the Internet experience, we started to explore the possibilities of replacing the website with a new media, independent of connections or

limitations of time use, less susceptible to go offline, etc. Some qualities of a CD-ROM seemed perfect to solve or minimize at least some of the issues:

- a CD-ROM is portable;
- a CD-ROM is a reliable and large enough media to content all the course material;
- it is independent, more stable and faster than an Internet connection and its traffic;
- it does not have an appeal to navigate outside the contents.
- it can easily include and play large files, AVI animations and even videos.

In the second semester of 2003 we decided to replace the website with an updated CD-ROM which includes short, interactive lessons on difficult topics - typically projections, perspectives, sections and the basics of the course. These lessons are illustrated with new 2D and 3D interactive animations (Fig. 8). As usual, the classes contents are introduced with the assistance of the animations and interactive models, now from the CD-ROM and not from a website.

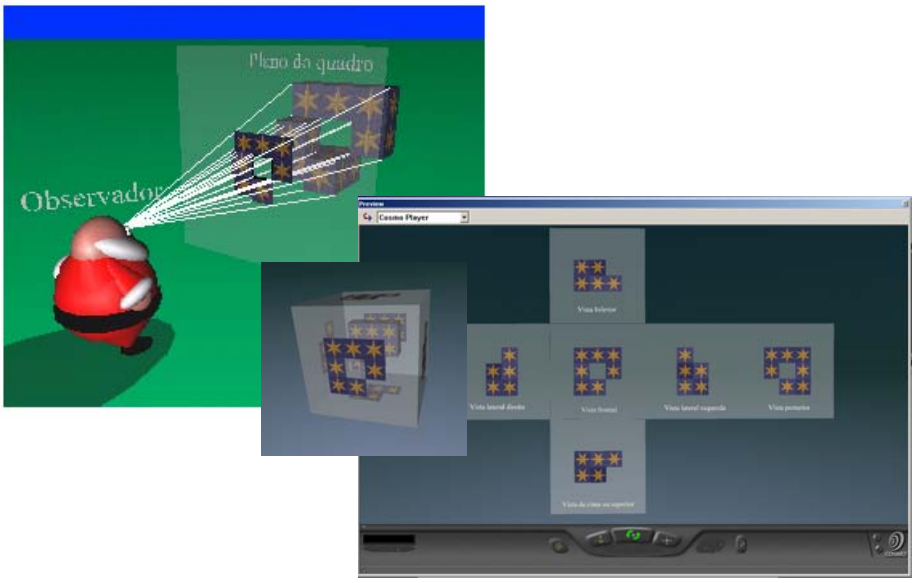

Figure 8. The CD-ROM includes more interactive animated VRML models on almost all the courses´ contents.

6. Highlights of the evaluation of the CD-ROM and the methodology

The CD-ROM is provided to the students with a copy of some printed material. It is used to support the teaching and learning process. Each new

concept or subject is illustrated with its animations and 3D interactive models.

With the introduction of this more stable, portable and accessible media, there was an expectation on the improvement of the time spent studying the provided material.

The result of this experience demonstrated that the previous scenario on the lack of the students´ interest did not change. Even providing a material that could contribute to their learning process with interactive and animated tools, the expectation could not be achieved.

In 2005 and 2006, surveys were placed to obtain the students profile and to evaluate the use of the CD-ROM and the course. Both results were similar and showed the same previous students profile: 96% of the students did not have any formal knowledge or training in drawings and 84% did not consider the Technical Drawings course fundamental for their education (2006 survey).

The survey showed that, in general, the reasons for the low performance are the same identified when using the Website, except for the better and easier access to the material provided. The figures below exemplify the result of this survey:

- 84% of the students believed that the new methodology using computer interactive resources is essential for the learning of the course; 13% disagreed with it and 5% preferred books or handbooks.
- 9% bought the CD-ROM only after the first test and 3% did not have it until the end of the course.
- From the 15 exercises of the CD-ROM for each test, 26% solved only 1 to 3 exercises and 31% solved none affirming that the practice in the class was sufficient.
- 18% did not use the CD-ROM for their theoretical studies and 11% did not use it at all.
- 71% though that computer graphics and 3D modeling are complementary and reinforcement techniques to hand drawing and visualization and 10% preferred the learning of AutoCAD instead of 3D modeling and VRML. These students claimed that the market asks for AutoCAD skills.

Some figures repeat the previous findings of the topic 4 of this paper:

- the students found the CD-ROM´s theoretical material helpful and of easy understanding, but less then 10% of them used it to reinforce class contents;
- around 80% considered that they have seen and learned enough when the contents and the material of the CD-ROM - animations, models, etc. - was shown and explained in class. These students only read the CD-ROM to solve exercises the day before a test;
- 100% of the students did not explore the CD-ROM and searched for further information as they do in recreational ones;

- from the students who have tried to solve the CD´s exercises, 100% tried to print its contents. As there are many 2D and 3D models and animations not possible to print, there was a strong demand for printed material;
- 27% of the students did not try to solve the problems by themselves. They had a feeling of good understanding just reading the proposal of a problem and visualizing its solution with the included 3D VRML models.

7. Conclusion and future work

The teaching method for the learning technical graphics and developing visualization turned out to be an improvement of the experience in 1991/1992, using advanced resources such as Internet, animations, virtual reality or 3D modeling in VRML combined with traditional pencil-and-paper drawings.

The resulting methodology is not based in any other previous work or experience. It was developed by experimentation along the way, since 1991, putting together our experience of teaching technical drawing and our own research on computer graphics, 3D modeling and virtual reality held from the late 80´s.

We are always testing and seeking for better ways of supporting learning with new material and resources. We have no indication that the change of media from the website to a CD-ROM has improved the interest on the didactic material or on the discipline. A reported little improvement in the time spent studying seems to be related to the easy of access and speed of viewing without an Internet connection. Some reported progress in the understanding may be attributed to the addition of more animated material and the step-by-step PowerPoint presentations in the CD-ROM.

The next steps will be a change of the metaphor and development of new educational material: instead of the metaphor of a window to the virtual reality world in webpages, we are developing virtual worlds similar to 3D games in which the students can play, listen, read, test and learn about the same matter of the CD-ROM.

Nevertheless, the last surveys among the students pointed to an unexpected issue: as the contents and the exercises are more clearly explained through the interactive material, the students feel unnecessary to make drawings and solve the problems by themselves. Without the practice of drawing, they are not able to accomplish the hand-drawing exercises in the tests.

This issue can be difficult to manage and raise questions on how to stimulate experimentation and practice, the need of hand drawing and the limits of explanation.

Most of the CD-ROM contents can be accessed at www.epratini.arq.br. To enter the site, view and interact with the 3D models and animations, please install a free VRML browser such as CosmoPlayer or Cortona) (http://ovrt.nist.gov/cosmo/downloads/cosmo_win95nt_eng.exe).

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