Design and Use of a Multimedia Trainer for the Subject Descriptive Geometry

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ABSTRACT: Less and less time is being dedicated to Descriptive Geometry in Technical Careers. For that reason, a multimedia application that allows us improve and optimize the teaching–learning process in the resolution of typical problems of this subject has been designed. Easy of use, interactiveness or efficiency are characteristics that can be related to this application. In this article, we describe the more important aspects of the developed Multimedia Trainer, as well as the results obtained in an experience with students with the purpose of evaluating its possibilities of use. ©2008 Wiley Periodicals, Inc. Comput Appl Eng Educ 17: 13–24, 2009; Published online in Wiley InterScience (www.interscience.wiley.com); DOI 10.1002/cae.20164

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INTRODUCTION

The time assigned to the subject Descriptive Geometry being taught in the specialties of Mechanical and Industrial Engineering is being reduced.

The systematic work of methodological improvement maintained by our staff of teachers has been focused on the improvement of the teaching techniques and methods the subject and has allowed, partly, to cover this deficit of time. Nevertheless, there are certain areas of contents and abilities that cannot be entirely adopted in the teaching–learning process, with the consequent lessening of the quality as to the formation of the professionals that teach this subject [1]. Also, not all types of students are capable of developing their learning paths by themselves [2].

The investigations [3–5] show that there is a direct relationship among the student's degree of orientation toward the development of the independent work, the motivation toward the activity and the efficient use of the time, that is visible through the

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academic results, given by an improvement in the qualifications and in the development of abilities and capacities in order to achieve the correct resolution of the problems posed to them. Other factors affecting learning outcomes can be social elements in the learning environment or a lack of distinction between major and minor issues in the content [6].

For the resolution of the typical problems of this subject, methodologies for their resolution have been developed [7]. These methodologies have been validated by means of their application during several courses. These succeeded in leading the students to the correct resolution of the problems and the development of their logical thought [8]. However, the methodologies are not always accessible, at least in an explicit manner, in the bibliography available to the students.

The work carried out in the field of Computer Assisted Learning (CAL) has demonstrated its effectiveness in the teaching– learning process of the graphic subjects [9], being able to highlight the use of them in engineering degrees [10–13]. An example of this is the "Package of Programs for the realization of educational activities and for the independent work in Descriptive Geometry" [4]. These programs are no longer in use due to the technological changes in the hardware; and on the other hand, as the first attempt to use of computerization as a means of teaching the subject a series of difficulties arose. Here in particular, linear navigation that characterized them and the absence of the use of the 3D approach. Today, with the possibilities that the elaboration of multimedia products present, these programs can be reprocessed in order to improve the teaching–learning process of Descriptive Geometry [14].

The results of the investigations carried out [15–17] point out the fact that these technologies offer significant contributions to education, they indicate enough potential value to justifying keeping on investigating on the use of the multimedia with educational purposes [18,19].

Under the current conditions, the necessity to optimize the teaching- learning process with a view to making a more efficient use of the classroom time is presented as fundamental to achieve the assumed objectives without affecting the quality of the process. How can it be achieved? What component of the process requires modifying, and improving to achieve its optimization? One of the ways to solve this problem is the use of the new technologies of scientific information.

From this problem, the following work was defined and tackled: to design, to develop and to evaluate a means of Computer Assisted Teaching to train the students in the methodologies of resolution of the typical problems of the subject Descriptive Geometry, since the application may be used by instructors in a complementary way for their courses [6].

As specific objectives of this work, we defined:

- To elaborate a means of CAL for the training in the methodologies of resolution of the typical problems of the Topic "Projections of Elementary Geometric Bodies" of the subject Descriptive Geometry.
- To evaluate of the product with students of Mechanical Engineering.
- To restructure the Course of Descriptive Geometry in such a way that the use of this product with the other traditionally used means is integrated.

In this article, the results obtained by means of the use of an application that facilitates the student in the resolution of exercises of Descriptive Geometry are explained.

GENERAL CHARACTERISTICS OF MULTIMEDIA TRAINER

The application presented in this article allows us to improve the teaching–learning process of resolution of typical problems of the subject "Descriptive Geometry." For its design, an author tools (ToolBook) was used. ToolBook is a development environment for the creation of materials for courses which support some objects oriented characteristics, as well as other benefits like visual programming, elements of word processor and a programming language called OpenSript [20].

To develop this application, the contents corresponding to the Topic "Projections of Geometric Elementary Bodies" were selected, distributing them in four blocks: Projections of Polyhedrons, Intersection of Polyhedrons with the Plan, Intersection of Polyhedrons with the Straight line and Reciprocal Intersection of Polyhedrons. Therefore, it is necessary that the student acquires previous knowledge about the Theory of the Projections, as well as methods of Descriptive Geometry for the solution of problems in which Elementary Geometric Bodies are present. For example, to understand the intersection of a prism and a pyramid it is indispensable to previously know how to represent both polyhedrons. In that aspect, teachers play a very important role since they must assure that students acquire an appropriate base of knowledge,

which may be one of the most critical aspects in the teaching methodology in which the tool presented in this article is integrated.

With Multimedia Trainer, we wanted the creation of a friendly environment for the training in the resolution of problems of this topic by means of the combination of image, text and sound, as well as training the students by means of a diversity of exercises. Furthermore, guarantee an immediate response to their accomplishments and errors, in such a way that knowledge can be built on solid bases.

In the process of designing the software the following approaches have been kept in mind [21]:

- Interaction between knowledge and the user: the student's activity is the fundamental approach on which the use of the software is based. For this there is a plan establishing its use as part of the learning.
- Contribution to the development of communication abilities by means of an interface that favors the appropriation of the technical terminology, re-creation and association of concepts. The development of the graphic language that makes up the engineer's form of basic expression is facilitated.
- Development of meta-cognitive strategies: To learn how to learn. The student elaborates his/her orientation based on learning self-control. It promotes the association of knowledge, the logical organization and the re-creation of concepts.
- Evaluation as a means of learning. The user will be informed at every moment about the results being accumulated during the process.
- Individual attention to the student. The possibility of free navigation and appropriate feedback to the individual results are guaranteed throughout the training.
- Amplification of the knowledge. By designing software interface the student is aware of the many possibilities of computer science.
- The elaborated version has flexibility for its self-development due to its modular construction, so that it enables enlargement in future versions.

It is necessary to highlight that it does not only interest effectiveness, but also efficiency because the class hour has become an obstacle to achieve the execution of the objectives, knowledge and skills to develop. It is important to design the means that allow students to appropriate knowledge and skills each time in a more independent, autonomous way.

The easiness of use of the application is another important aspect in the presented tool, given that the simplicity of the interface and the interactive help always maintains students informed about how to proceed. The own dynamics of the questions outlined by Trainer guides students in the use of it.

Also, Trainer allows us to teach the student to think, to reason and to develop skills by means of the realization of tasks that allow the transfer to new situations of the problem. Here the principle of teaching solution strategies are essential, and not just to stay in the mere solution of an exercise as an example of application of the studied method.

DESCRIPTION OF THE MULTIMEDIA TRAINER

After opening the application, the user must introduce his complete name and the academic group to which he belongs to begin the session (Fig. 1). It is necessary to point out that the students have free access to the exercises which is why the professor must guide them about the exercises they should carry out.

Once the main page is accessed, the student can choose one of these four topics (Fig. 2):

- Projections of geometric bodies.
- Intersection of the plane with geometric bodies.
- Intersection of the straight line with geometric bodies.
- Reciprocal Intersection of geometric bodies.

Each one of these topics connects to another Menu where the types of exercises appear. Thus, for example, in the case of Intersection of the Plane with geometric bodies, a menu is opened that presents the following options:

- Intersection of the plane with polyhedrons.
- Intersection of the plane with surfaces.

Each type of exercise connects to a Menu of Exercises (Fig. 3). Each of them displays 10 exercises with a similar level of complexity. The students can select the exercise they want and can do it as many times as they want.

Once an exercise is selected, the module that takes charge of the identification of the bodies is activated. This works equally for all the types of exercises, except for Reciprocal Intersection of bodies, in which it is necessary to identify the two bodies. Multimedia Trainer asks students to choose which body they will identify first (Fig. 4).

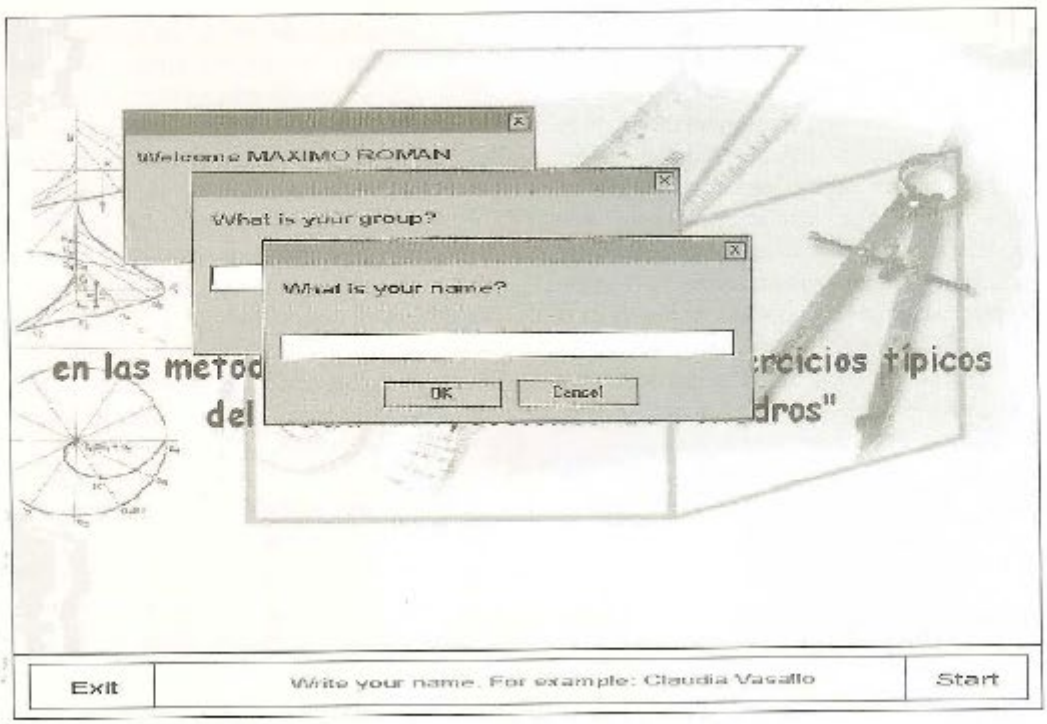


Figure 1 Access to multimedia trainer.

In order to differentiate the bodies, different colors are used for Body 1 and Body 2 (Fig. 4). After the selection of the body, the screen that allows the identification is accessed, where the resolution of it begins.

In Figure 5, the characteristic format of the screens used for the resolution of the exercises is shown. The graphic development of the selected exercise is displayed in the left part of the window and the area for the communication with the student is located in the right part, where, one by one, the questions that allow to execute the methodology of resolution of the exercise will appear.

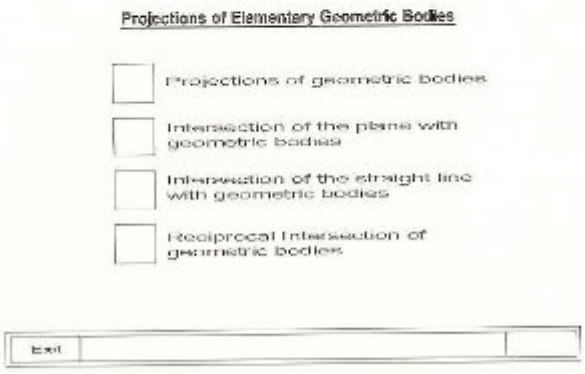


Figure 2 Window for the selection of topic.

Below the two previous areas, the one that summarizes the resolution of the exercise, step-by-step, is located (Fig. 6). This area, for the case of the identification of the bodies in the Reciprocal Intersections of Bodies, is divided in two parts; one for each body, in the rest of the cases there is only one area.

The student's training in the methodology of resolution of the exercises will be carried out by means of questions which the students will be able to respond to by means of lists of options or buttons that allow them to select the correct one (Fig. 7). The sequence of designed questions establishes the methodology of resolution of the exercise in which the student is trained.

As a student progresses answering to the questions, the summary of the complimented aspects of the methodology is shown in the boxes of the inferior part of the window. Also the gathered information will be stored in the file that is automatically created when initiating the session. Once each step of the methodology is concluded, the students will be able to have access to all the information about their progress (Fig. 8).

In order to familiarize students with the use of the application, the possibility of developing a training activity exists so that they complete some exercises under the direction of the professor. However, the

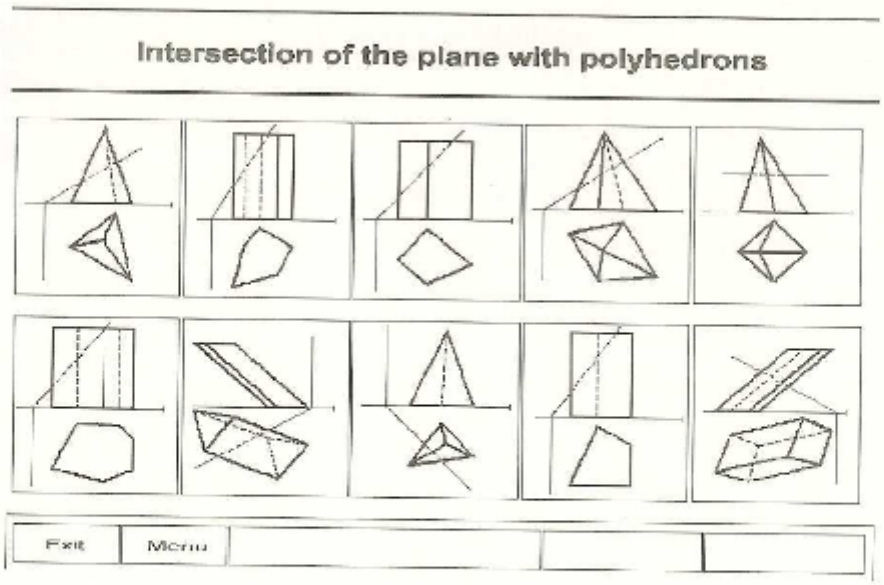


Figure 3 Window of selection of exercises.

Interactive help and the own methodology of resolution of the exercises help to lead students in the use of the application.

It is necessary to indicate that Multimedia Trainer allows users the printing of exercises (Fig. 9). All the printed data are automatically filled so that the students only have to select if, besides printing graphic development of the exercise, the summary of the analysis of the exercise and/or the methodology of resolution of the exercise type will be included.

WORK METHODOLOGY

The trainer is elaborated for the contents of the Topic "Projections of Elementary Geometric Bodies" involving them with respect to:

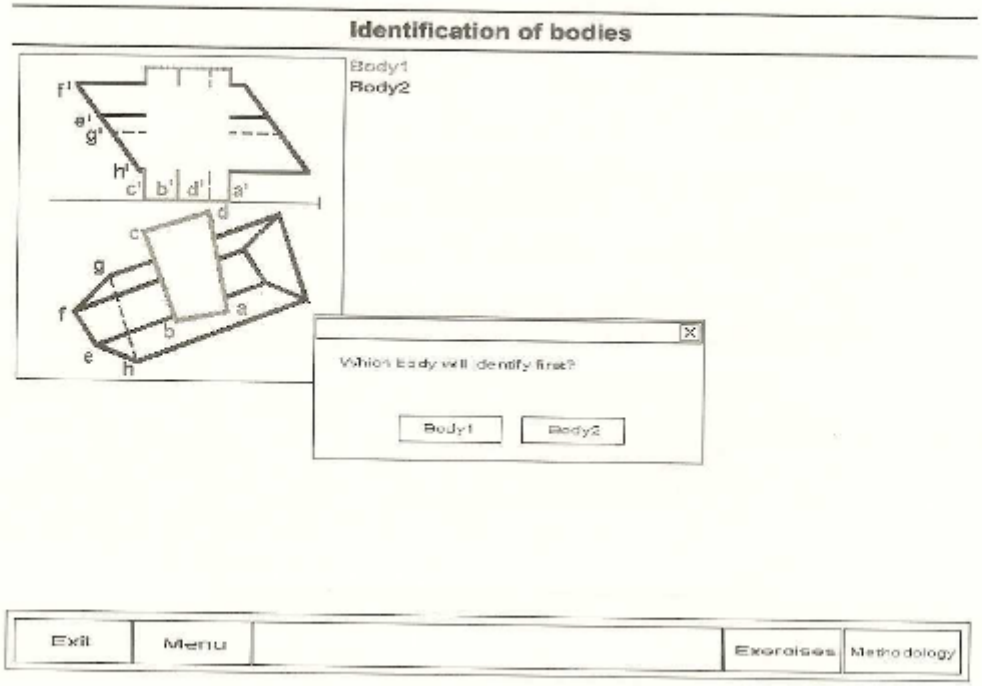


Figure 4 Window of identification of bodies.

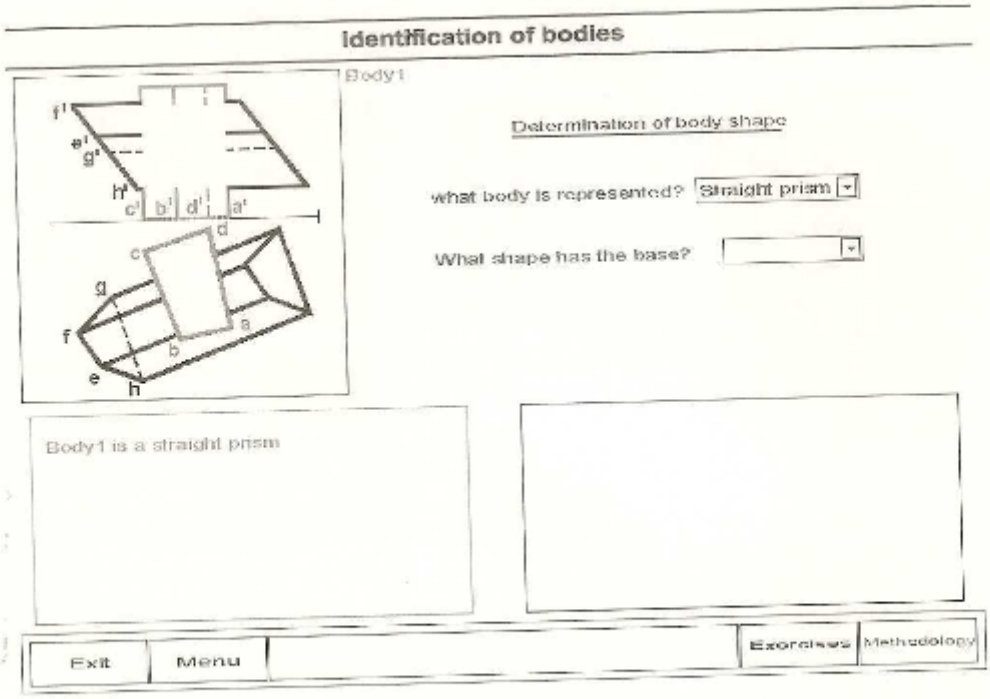


Figure 5 Format of window for the resolution of exercises.

- Projections of geometric bodies.
- Intersection of the plane with the geometric bodies.
- Intersection of the straight line with the geometric bodies.
- Reciprocal Intersection of geometric bodies.

This topic takes up more than 50% of the subject classroom time, and covers the problems through which the methods studied are generalized

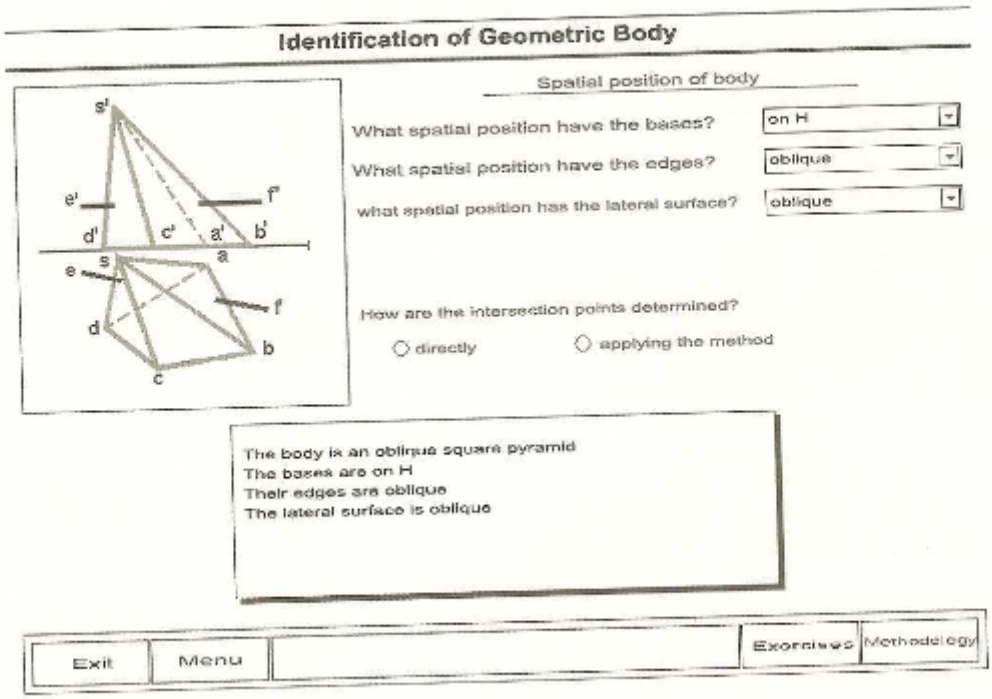


Figure 6 Window of resolution of exercises.

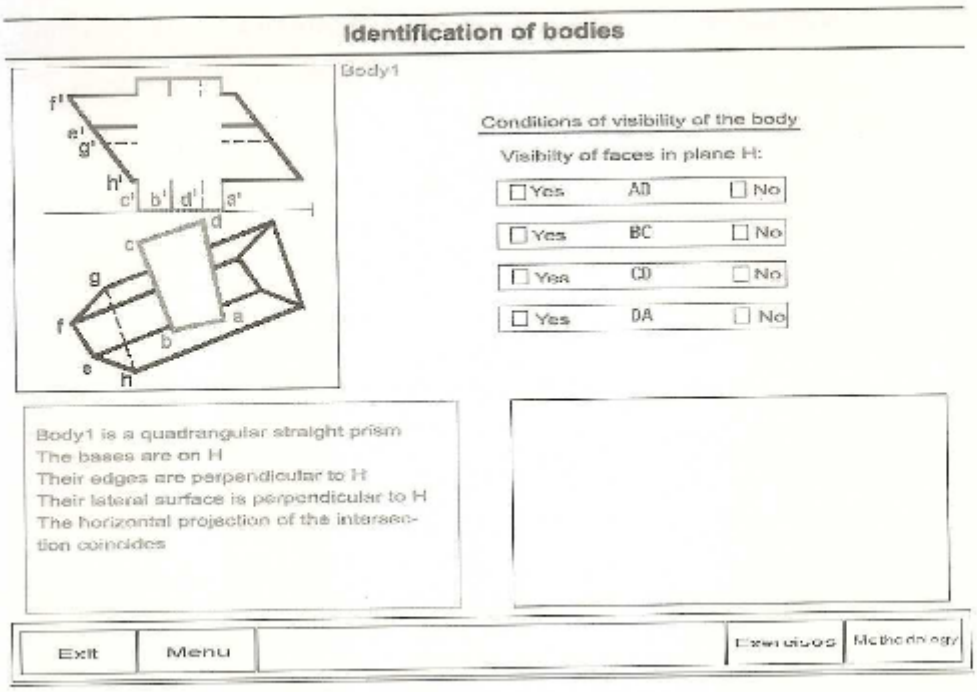


Figure 7 Window of analysis of the visibility.

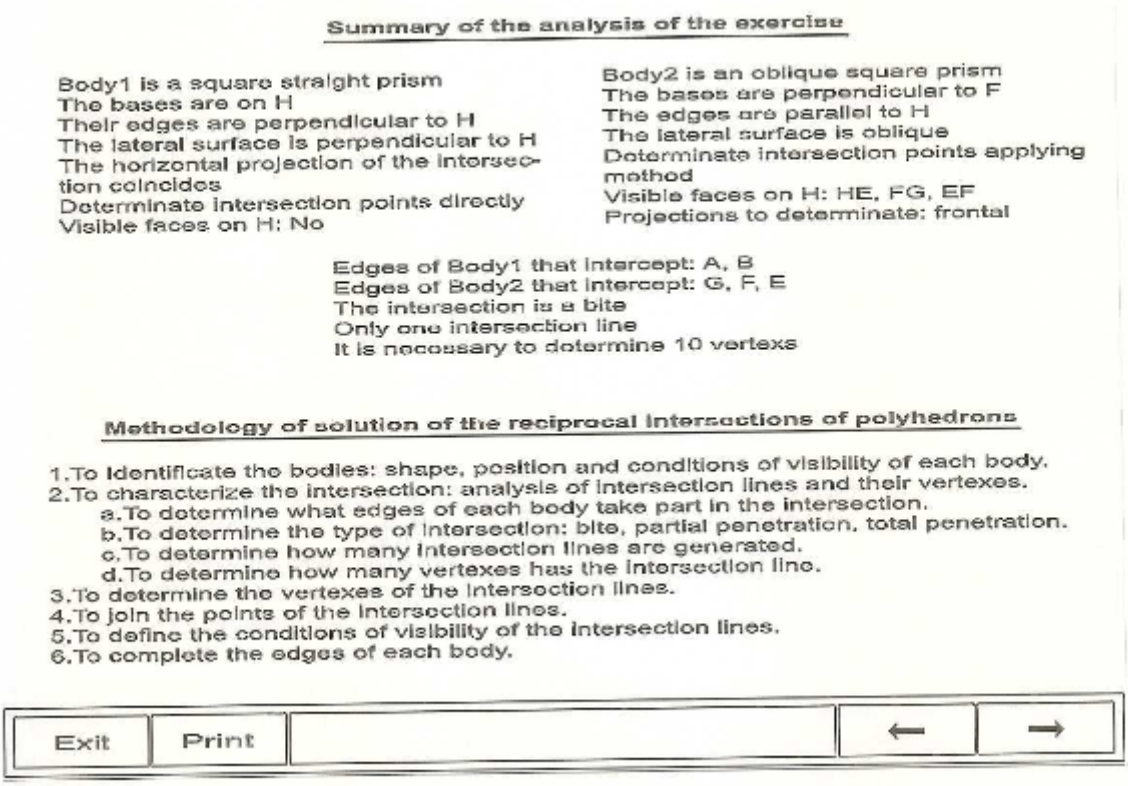
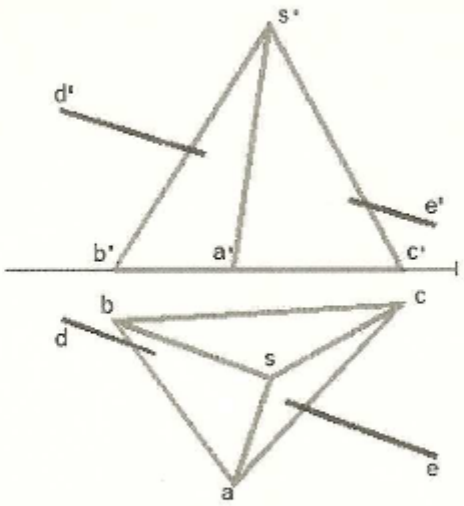


Figure 8 Summary of the analysis of the exercise.

Name: Claudia Vasallo Group: IM-01 Date: 11 Oct RecPol-01

To determine the intersection points of the straight line with the body.



Summary of the analysis of the exercise

The body is an oblique triangular pyramid
The base is on H
Their edges are oblique
Determinate intersection points applying method
Visible faces on H: SAB, SBC, SCA
Visible faces on F: SAB, SCA
The straight line is oblique
The straight line cuts to the lateral surface
A frontal projecting plane should be used
The produced section is triangular

Methodology to solve the intersections of the straight line with the Polyhedron

1. To identificate the body: shape, position and conditions of visibility.
2. To characterize the intersection.
   a. To determine the position of the straight line
   b. To determine which parts of the body are affected by the straight line.
   c. To analyze which is the suitable plane to solve the intersection.
   d. To analyze which shape has the section (triangular, square, circular).
3. To determine the intersection points.
4. To determine the conditions of visibility of the straight line.

Figure 9 Window of impression of exercises.

and applied. The problems of reciprocal intersection of bodies constitute the most complex and their solution requires having trained the students previously in the methods suggested for this subject.

The potential users of this product are the students enrolled in the engineering degrees. For their validation students were randomly selected from the first year of the studies of Mechanical Engineering of the Courses 2000/2001, 2001/2002, and 2002/2003. In each course the students were divided in two groups:

- *Control Group*: an introductory class of the topic was given to the students of this group and then they passed to develop their autopreparation work with the resources that have traditionally been used in teaching.

- *Experimental Group*: After an introductory class of the topic, the students made autopreparation work with Multimedia Trainer.

The objective of these tests is to study the improvement for the student of Descriptive Geometry that the use of the trainer in the teaching–learning process will mean. For that reason if the Experimental Group has solved the exercises more efficient and more effective than the Control Group is observed.

Evaluation and control techniques were used, as well as interviews and surveys, intended to achieve the assessment of the effectiveness of the product. As part of the validation a pre- and post-test with a view to being able to compare the results among those who used the product and those who did not use it was carried out [22].

The product is elaborated to be used independently on the part of the student, without the teacher's presence; on this basis they can train themselves in the above mentioned methodologies for the given topic.

An essential aspect of the work carried out is the search for higher efficiency of the work of the students' self-preparation, looking forward to guaranteeing the efficiency of the teaching–learning process itself.

OBTAINED RESULTS

To establish the effectiveness of the method, yield tests were designed that allowed us to know how much the users learned with the means. That's why the technique of the pre- and post-test was used with the Group of Control and the Experimental Group. Once all the data was gathered, they were classified and processed to conclude later with the phase of analysis in order to establish the consequences that can be deduced with regard to the purpose of the investigation.

Before beginning the tests, a study (by means of the test of Mann–Whitney) was made to verify that there were not significant differences among Control and Experimental Groups. For this study, academic index from the students at the moment of their entrance to the career was used. The hypothesis was not rejected and we concluded that significant differences in the academic index of the Control and Experimental Groups did not exist, reason why had validity to carry out the experiment.

The tests were carried out creating the suitable conditions inside the own process of teaching–learning of the subject, in the moment that the students study the contents and programming the

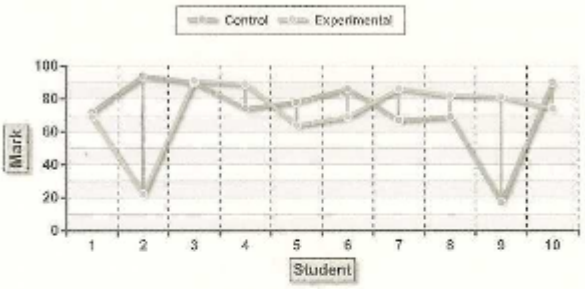


Figure 10 Results of Pre-test of Experiment A.

different activities with the enough immediacy to avoid that factors unaware to them behaved as unknown variables.

Thus, the results of Pre- and Post-test in Control and Experimental Groups obtained with the students of the course 2000/2001 (Experiment A) are shown graphically in Figures 10 and 11. It is possible to observe that in the Experimental Group there is an improvement of the academic results. Also, we could verify that the students that used Multimedia Trainer had a better performance in the resolution of the exercises and they solved them in a shorter time.

The information of the first test allowed us to gather elements for the improvement of the mean that was subjected to a second test with the students of the course 2001/2002 (Experiment B) that were distributed in the two groups, each one of them with 17 students. As in the previous test, satisfactory results were obtained about the use of Trainer, as it is shown in Figures 12 and 13.

Finally, a last test (Figs. 14 and 15) with students of Mechanical Engineering of the course 2002/2003 was carried out (Experiment C). Studying the data obtained from Control and Experimental Groups separately, it is observed (Fig. 16) that in both cases exists a significant difference between the results of Pre- and Post-test, but the Experimental Group obtained a qualification average of 94.40 points

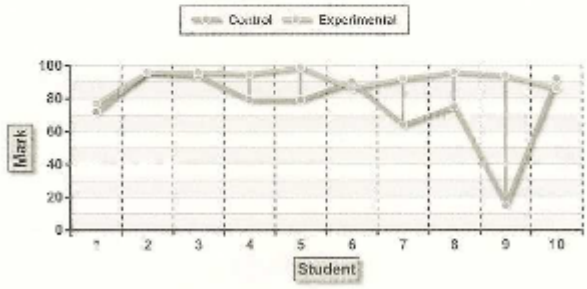


Figure 11 Results of Post-test of Experiment A.

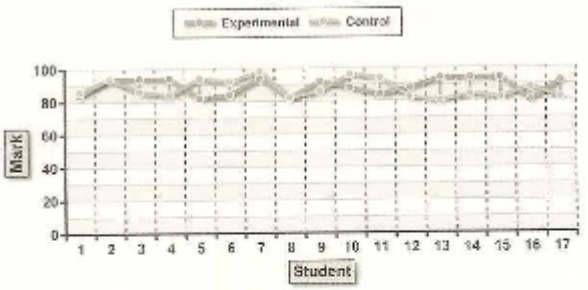


Figure 12 Results of Pre-test of Experiment B.

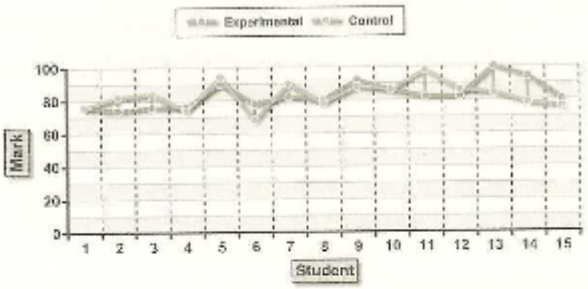


Figure 14 Results of Pre-test of Experiment C.

whereas Control Group only obtained 87.33 points. The Experimental Group improved their average in 11.2 points, whereas Control Group only in 4.5 points, which demonstrate that the performance of the students in the resolution of the exercises is improved when incorporating Multimedia Trainer. Here also we can observe that when the use of Trainer is systematized in the teaching–learning process, the positive results become more remarkable.

On the other hand, when observing the work of the students in the following educational activity, a more efficient work of those that have used the trainer is verified. In other words, they solved the exercises in a more independent way and in a shorter time.

CONCLUSIONS

The trainer constitutes a Multimedia System for the study of typical problems of the subject of Descriptive Geometry that guarantees the training of the students in the methodologies of resolution of exercises in an autonomous way; it allows us to have a great number of exercises and of the evaluation of the autopreparation work.

The structure in modules allows the adaptation and/or amplification of the trainer corresponding to the educational necessities that can be presented. Their use is perfectly articulated with the development of manual abilities of the students, this aspect is considered of great importance in the process of teaching learning of this subject.

An important conclusion about the use of Multimedia Trainer is that it can become a fundamental role in the development of the capacity to learn to know the methodologies of resolution from typical exercises of the subject of descriptive Geometry.

The results obtained in quantity and quality in the experimental groups were significant with regard to the results in the control groups. The Tests carried out allowed checking the trainer's usefulness; contributing the necessary elements for the restructuring of the

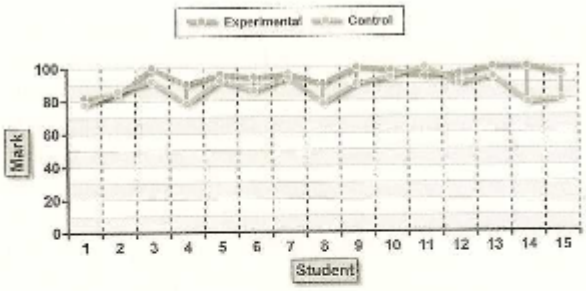


Figure 15 Results of Post-test of Experiment C.

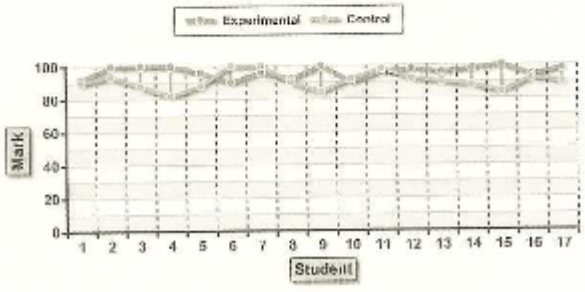


Figure 13 Results of Post-test of Experiment B.

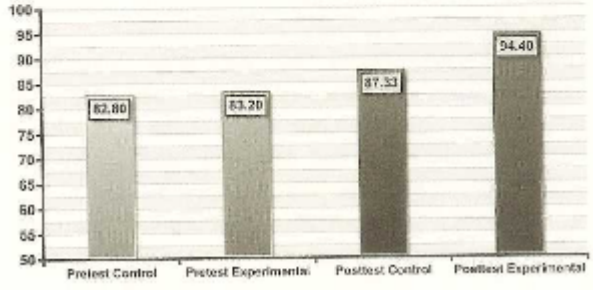


Figure 16 Averages in Experiment C.

process of teaching–learning of the subject. Also, the similarity of these results guarantees the trustworthiness of the investigation developed. The instruments and procedures have generated similar results when they have been applied to similar users in similar situations.

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