Development of interactive materials by engineering students using the Descartes applet.

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ABSTRACT

In a degree course such as Forestry Engineering, the general teaching objectives consist of explaining and helping students to understand the principles of Mechanics. For some time now we have encountered significant difficulties in teaching this subject due to the students' lack of motivation and to their insufficient prior preparation for the topic. If we add to this the discipline's inherent complexity and the students' preconceptions about the subject, these teaching difficulties become considerable. For this reason a series of didactic activities have been introduced sequentially in the teaching of this subject. This work describes the methodology, procedure and results for the action of developing a work project in groups using Descartes software. The results of this experiment can be considered very positive. Some of the critical preconceptions for learning the subject can be corrected, and the tutoring process in the classroom contributes to an improvement in teacher-student communication. Since this scheme was established, the number of students taking part each academic year has increased, and this is the group with the greatest percentage of passing scores.

Keywords: applet, Descartes, Mechanics, preconceptions.

1. INTRODUCTION

The primary objective of the first year of Mechanics in a Special School for Engineering should be to develop the students' capacity to analyse any proposed mechanical situation in a logical and simple way by applying basic principles which have been correctly assimilated ([1] Covián Regales, E., 2004); in short the teaching should have an applied character.

The achievement of this objective is conditioned by the content of the syllabus and by the teaching methods used, which should be aimed at ensuring the students' comprehension of these principles in order to obtain the proposed objective.

In a degree course such as Forestry Engineering, the general teaching objectives consist of explaining and helping students to understand the principles of Mechanics. These principles can be accurately expressed in mathematical terms and constitute powerful tools which can be applied to solving the problems arising in Nature. The acquisition of this knowledge allows students to tackle subsequent subjects based on or related to Mechanics (Hydraulics, Electrotechnics, Calculating Structure, Reforestation and Forest Machinery and Forestry Production) and Technology (engines and thermal machines).

However in the Forestry Engineering course given in the UPM, students in the first years have tended to award more importance to subjects with a greater biological content than to subjects related to engineering. This may be due to the fact that the students have an increasingly poor preparation in Mathematics and Physics, and to the growing social value accorded to the knowledge and concern for the environment ([2] Tévar Sanz, G., 1998).

We are now encountering significant difficulties when teaching Mechanics and Mechanisms, due both to the students' lack of motivation and to their insufficient prior preparation in the subject. If we add to this the complexity inherent in the discipline and the students' preconceptions regarding this topic (ideas which are not of a strictly scientific nature to explain natural phenomena), the difficulties for teaching become considerable.

For this reason, a series of didactic activities have been introduced sequentially in the teaching of this subject. These are differentiated into actions which concern the teaching methodologies themselves (the way the subject is taught), and actions involving new methods for assessing students' knowledge and skills.

Teaching methodologies

1. Creation of interactive applets as a teaching methodology (2002/03 academic year).

Knowledge assessment

2. Incorporation of a module on prior knowledge of Mechanics (2003/04 academic year).
3. Assessment of preconceptions regarding the concept of force (2004/05).
4. Development of a work project in groups using Descartes software (2006/07).
5. Incorporation of the subject onto the Moodle platform (2008/09).

This work describes the methodology, procedure and results obtained in the development of the work project in groups with Descartes software.

2. MATERIALS AND METHODS

The average results for the subject of Mechanics and Mechanisms obtained by the students in the last five years are far from satisfactory (26% pass, 26% fail and 48% no show).

As the two lecturers in charge of teaching this subject, we are well aware of this situation and have made changes to both the programme and the teaching methodology, as well as to the methodology used to evaluate the subject. Geometry-based elements have been eliminated from the programme. Interactive visual teaching materials have been incorporated into the teaching methodology in order to improve the understanding of the concepts.

Programs for mathematical calculations and for simulating phenomena are the most useful for improving students' understanding of the underlying concepts of mechanics. Since the 2002-2003 academic course, a series of applets were designed and have been integrated into the teaching programme for the subject. The concepts addressed include: analysis of velocities and accelerations, obtaining the fixed pole and the movable pole, stationary circumference and the circumference of inflections, method of sections for calculating trusses, shocks, etc ([4] Tévar-Sanz & Grande-Ortiz, 2007).

The assessment of students' preconceptions about the concept of force is discussed below. In order to detect these preconceptions the Force Concept Inventory (FCI) has been carried out on all students since the 2004-05 academic year, before starting the specific teaching of this subject. FCI is a multiple-choice test designed to determine the understanding of the basic concepts of Newtonian physics. It is essentially used as a tool for assessing the efficiency of teaching and to detect preconceptions in Mechanics. The results of this test have enabled us to detect students' most critical preconceptions for the correct learning of Mechanics. Specifically, the most common preconceptions when approaching the study of planar kinematics are the following:

- failure to differentiate between position and velocity
- failure to understand the vectorial nature of velocity and acceleration.

Regarding the assessment of knowledge, in the 2006-07 academic year we introduced a supervised work project to be carried out in groups of two people as an obligatory and evaluable activity in the kinematics module. During the first semester, the classes took place in the computer classrooms assigned for that purpose. The tool used in this work is the Descartes nippe, a software program developed by the Ministry of Education ([3] MEC) that can be downloaded free.

The Descartes project was created for the purpose of exploiting the advantages of computers and the Internet to offer teachers and students in primary and secondary education a new way of teaching and learning. The Descartes nippe is a program developed in the Java language (applets) which enables the creation of interactive scenes similar to electronic blackboards. In addition, the nippe can be configured; that is to say, it can be handled by the users without any need for programming knowledge.

The methodology used is described below.

First a two-hour preliminary session is given in the computer room in order to demonstrate the features of the tool. The Descartes project includes a tutorial which allows students to study the tool by themselves. Then the students are divided into groups and given a problem involving the kinematic analysis of a basic mechanism (slider-crank four-bar), which must be done by all the groups in order to familiarise them with the tool.

In this same session each group is given a collection of mechanisms (an assortment of about 20), from which they must select one (Figures 1 and 2).
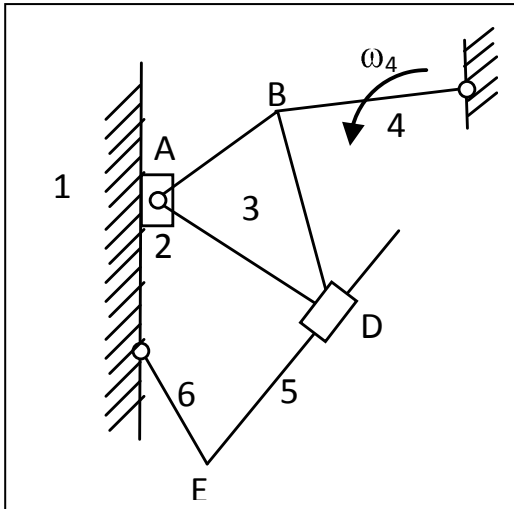
Figure 1: Example of possible mechanisms for selection.
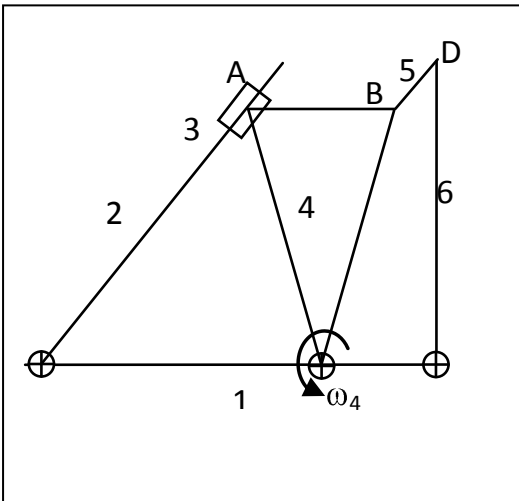

Figure 2: Example of possible mechanisms for selection.

The definitive assignment is done when the group has presented the kinematic analysis of the basic mechanism using the Moodle platform.

The groups carry out their work project in eight two-hour sessions in the computer classroom, under the supervision of the two teachers who give the subject.

They begin by drawing the assigned mechanism using segments with control points at the ends. Each segment is defined by using its control points (CP). The position of these CP can easily be changed by simply clicking and dragging with the mouse. This enables one mechanism to be transformed into another with the same configuration simply by moving the CP. Restrictions can be applied to the CP so that, in order to draw a crank, it is only necessary to submit the mobile end to a restriction which requires it to move around a circumference. To draw a slider the mobile CP only needs to be instructed to describe a straight line.

In the program used, a vector is defined with the pair of points corresponding to its ends [(a,b) (c,d)]. Starting with a known velocity, they calculate the velocities for all the points which define the configurations of the mechanism. This calculation is usually done using the relative velocity method. These velocities are associated to the CP, which makes it possible to check visually if they have been correctly calculated by simply moving the control points with the mouse. This way the relative velocity between two points of the same element will remain perpendicular to the segment which joins them.

The procedure for calculating velocities for the basic slider-crank four-bar mechanism (Figure 3) is the following:

- The angular velocity of the crank (OA) ω is the starting figure.
- The coordinates of end A (Ax, Ay) coincide with the components of vector OA. These components expressed in three-dimensional space (Ax, Ay, 0) and multiplied vectorially by the vector (0,0,ω) allow us to obtain the components of the velocity (v_A).
- The velocity of the other end of the connecting rod (B) is obtained by means of the vectorial equation which relates the velocities of two points on the same element:
$$v_B = v_A + \omega \wedge BA$$
The velocity vector v_B is determined graphically at the origin of the coordinates by calculating the intersection of two straight lines. One of them has the direction of v_B (horizontal) and passes through the origin, and the other is perpendicular to BA and passes through the end of v_A
- The velocity obtained must be transferred from the origin to the application point B.
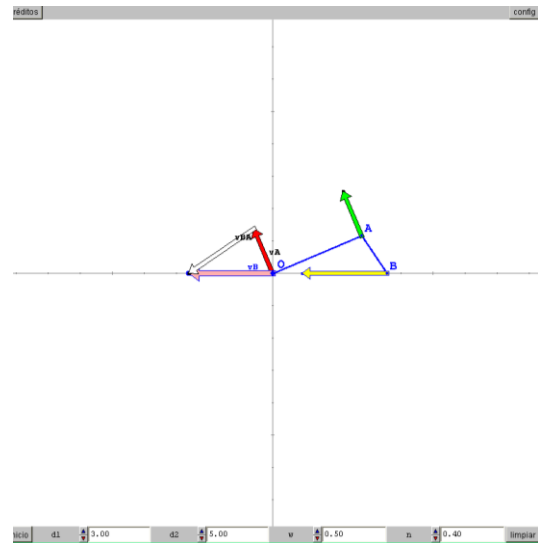


Figure 3: slider-crank four-bar

After preparing the work for a period of eight weeks, a provisional version of the project is presented using the Moodle platform. The work is subsequently revised personally with each group in the classroom.

From that point, the students have two weeks for the definitive presentation of the work project, after implementing the corrections identified in the review session.

Each work allows up to two points to be added to the score given in the partial assessment. The criteria for evaluating the work are:

- Degree of difficulty of the mechanism
- Correctness of the calculations
- Clarity of resolution and presentation
- Use of auxiliary variables
- Control points in articulations and sliders
- Operations and calculations presented in a separate document.

Figure 4 shows, as an example, two different configurations of a mechanism prepared by students in the 2009/10 academic year.
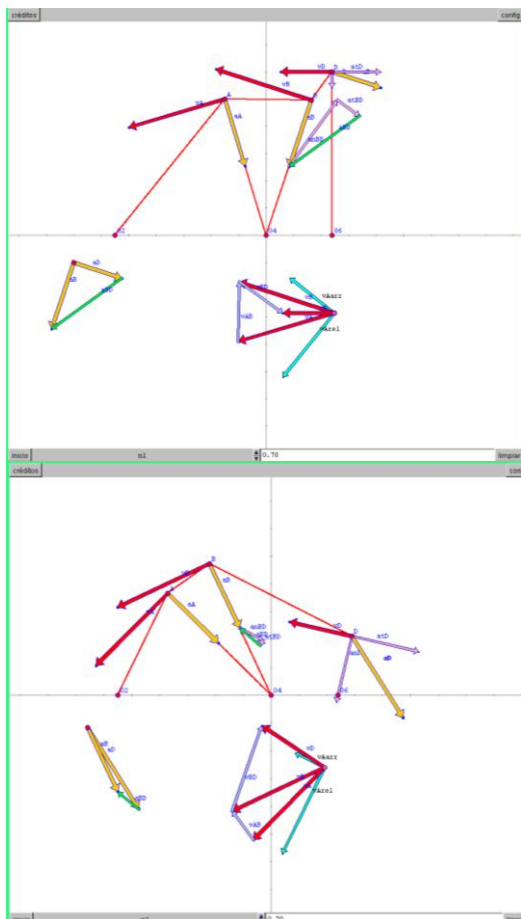
Figure 4: Configurations of a mechanism (example Figure 2).

3. RESULTS AND CONCLUSIONS

Since the introduction of the scheme for supervised work projects using Descartes software in the 2006/07 academic year, the students have completed a total of 145 projects. Table 1 shows the distribution of these work projects by academic year and the percentage of students who take part in the activity with regard to the total number of students matriculated.

Year	No. matriculated	No. projects	% students
2006/07	133	20	30
2007/08	139	22	31.6
2008/09	129	33	51.2
2009/10	100	26	52
2010/11	133	45	67.7

Table 1: Distribution of projects by academic year

As can be seen in Table 1, the percentage of students participating has increased progressively until it now exceeds 50% of the students matriculated. The figure for the current year is significantly higher as a result of the elimination of the degree course for Forestry Engineering, in compliance with the European Higher Education Area (EHEA). The highest final scores for the subject correspond to the students who took part in this experiment.

One of the main problems which arose during the development of the work is the calculation of the intersection between two straight lines. This system makes it possible to detect visually, and immediately, whether the point obtained analytically coincides with the point shown on the screen. Some students, after various attempts on paper, are ultimately able to obtain a mathematical expression using the Mapple.

Many students have considerable difficulty working with elements whose length may vary and which are rigid in reality. However it is helpful to use this method in order to modify the position of the elements without having to undertake the calculation of the simulation of the movement. The velocities can thus still be obtained correctly as the configuration is not modified. In addition, by moving the CP, it is possible to check that the velocities have been correctly calculated for any position.

The nippe in the Descartes project was designed to enable teachers of primary and secondary education to develop teaching materials. The use of this software by engineering students makes it possible to develop new skills and abilities. When the students create the material themselves, they have to analyse the problem in depth and at the same time graphically visualise their corrected calculations on the screen.

A large part of the students who display considerable reticence in handling the software at the start of the experiment are able to overcome this situation by the time they complete the work.

The results of this experiment can be considered very positive for several reasons: some critical

preconceptions for learning the subject (vectorial dimension of velocities and accelerations) can be corrected, and the tutoring process in the classroom leads to improved teacher-student communication. Since its implementation, the number of students taking part each year has increased, and this group demonstrates the highest percentage of passing scores.

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