Teaching methodology of the subject "Graphic Expression" using Web-based CAD tools

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Abstract

The implementation of the European Higher Education Area (EHEA) brings a change in the teaching methodology of the subject "Graphic Expression", focusing on the students as an active learners and the teachers as a guide in the learning process. To achieve this objective, a new teaching proposal with a self-learning graphic interactive Web environment was developed. This paper describes this educational strategy and the results obtained with this research, which is expected to be useful to analyze the adequacy of the proposed system for this subject in the new curriculum of the engineering studies.

1 Introduction

The introduction of new degrees adapted to the European Higher Education Area (EHEA) in Spanish universities has led to significant changes in teaching methods of Graphic Expression [1]. The teachers have had to adapt their methodologies to fit them into the new criteria with the intention of ensuring that the professor-based learning is replaced with a one based on the personal work of the student [2].

The students in the new degrees need to be able to solve problems and make decisions, which require an active learning based on the practice and discovery. Motivation plays a very significant role to achieve these goals and more important in the context of the information and communication technologies (ICTs) since the students have to set their training objectives and pursue them at their own pace.

Therefore, providing students with interactive graphical tools that facilitate and motivate their self-learning can be a significant improvement on the dynamic teaching of Graphic Expression [3]. Thus, if the students want to advance, they have to participate, to pay attention and respond to the requirements of the program. They cease to be a passive recipient of information to become an active receiver of this information.

The creation of interactive applications accessible from any geographic location and at any time allow to increase significantly the effectiveness and efficiency of tasks and services that otherwise would require enormous efforts by all concerned to finish them [4]. In addition, this type of Web-based graphic tools motivates the students by its virtuosity and dynamism, breaking the classroom routine to achieve a more attractive and varied learning [5-6].

This paper describes an innovative methodology used for the learning of the subject "Graphic Expression", which aims to combine the use of interactive graphic Web tools oriented towards the self-learning and the traditional drawing tools. Furthermore, an analysis of the experience for its implementation highlighting the most significant aspects to adequate the methodology to the new model marked by the European Convergence was carried out.

2 The subject

"Graphic Expression" is an obligatory four-monthly subject of the first course of Industrial Engineering at the University of Oviedo. It has 6 ECTS credits equivalent to approximately 150 student work hours (1 ECTS credit ~ 25 student work hours) [7].

The objective of this subject is to master the techniques of drawing and design with and without computer and to be able to apply them to solving problems in the engineering topics as geometric constructions or spatial vision. Therefore, the aim of this subject is that the students develop the following skill:

"Capacity of spatial vision and knowledge of the graphical representation techniques, both by traditional methods and the computer aided design applications".

The resulting ability is based on the following learning outcomes:

- *R1*: To understand and learn the fundamental principles governing geometric constructions.
- *R2*: To understand and learn the fundamental principles governing representation systems to interpret and represent engineering drawings.
- *R3*: To be able to understand and apply the rules of the representation and incorporate the use of technical terms in the language.
- *R4*: To be able to know, understand and apply the computer-aided design programs to represent engineering drawings.
- *R5*: To be able to understand, know and apply the graphical visualization techniques to improve the spatial vision linked to engineering.

It is intended that the subject is eminently practical, although previously some theoretical contents must be studied. These contents are divided into three units, as shown in tab. 1.

Units	Lessons
I. Introduction	Lesson 1 - The graphical language
	Lesson 2 - Computer Aided Design
II. Descriptive Geometry	Lesson 1 - Theoretical foundation of Dihedral representation system
	Lesson 2 - Dihedral representation of basic elements
	Lesson 3 - Relations between elements on Dihedral representation system
	Lesson 4 - Theoretical foundation of dimensioned drawing system applied to civil engineering
	Lesson 5 - Relations between elements on dimensioned drawing system applied to civil engineering
	Lesson 6 - Representation of Surfaces and volumes
	Lesson 7 - Axonometric perspectives
III. Technical Drawing	Lesson 1 - Technical standards in Engineering
	Lesson 2 - Standardized Views System
	Lesson 3 - Cuts and sections
	Lesson 4 - Dimensioning
	Lesson 5 - Tolerances and surface finishes
	Lesson 6 - Overview and parts drawing
	Lesson 7 - The design in the engineering

Tab.1 Theoretical Contents of the subject "Graphic Expression".

3   Methodology used in the subject

First, the Virtual Campus of the University of Oviedo is used as content and documentation support along the entire subject. In this way, the students can have, at any time, all the information needed to achieve adequate learning. It also provides a way of communication with the teacher to solve the doubts using tools such as forums or email. But this communication is bidirectional because the teacher can also use the platform to notify the students the incidents produced during the course.

The structure of the subject is composed of a series of activities which are described below.

3.1   Lecture classes

They are 24 sessions of 1 hour. In these sessions, the teacher analyzes, in a condensed form, those aspects that can be important, leaving the students the task of studying these topics at length to this end, the students can use the contents hosted in the Virtual Campus of the University of Oviedo as a starting point in their study.

3.2   Classroom practices

They are composed of 21 hours divided into two blocks.

A. Block I: Descriptive Geometry practices

The first 10 hours correspond to the learning of Descriptive Geometry (Dihedral representation system, dimensioned drawing system applied to civil engineering and axonometric system). The students will use a modular and interactive Web application oriented to facilitate the learning-teaching process. This application, called CADFLASH (www.cadflash.es) has the tools commonly used in any 2D-CAD applications (see tab. 2) with the purpose of using them in the learning of the topics indicated before (Fig. 1).

Group	Tools
General Tools	*Refresh screen, Redo action, Undo action, Zoom, Pan, Properties of entities*
Draw Tools	*Point, Line, Circle, Arc, Perpendicular bisector, Bisector, Parallel and Perpendicular, Text, Spline, Ellipse, Hatch*
Entity references	*Endpoint, Midpoint, Center, Intersection, Tangent, Quadrant, Node*
Editing tools	*Delete, Copy, Move, Dynamic Length, Rotate, Simetry, Polar Matrix*
Dimensioning tools	*Linear, Angular, Radial, Diametral*

Tab. 2 Tools available in CADFLASH.

Therefore, the student, through a series of exercises in this Web environment, can understand step-by-step the basic tools for the drawing of elements using different representation systems studied in this course. The exercises are grouped by Units and each of these units has the tools necessary to solve the exercises. These tools are chosen by the teacher in each Unit. For this reason, CADFLASH is considered a modular application.
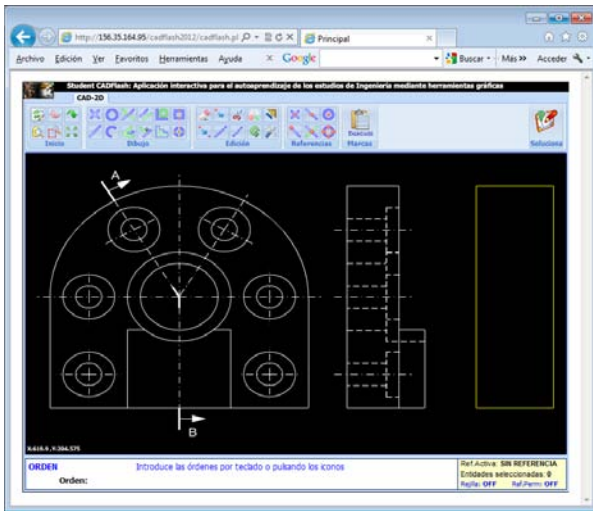
Fig. 1 CADFLASH interface.

Another advantage brought to the use of this environment is an automatic correction mechanism. When the student solves an exercise, the application gives a mark based on the degree of similarity with the correct answer (Fig. 2). If the mark obtained is equal or higher than the cut-off mark, the exercise is passed. Otherwise, the exercise is not passed and the student can retry it.
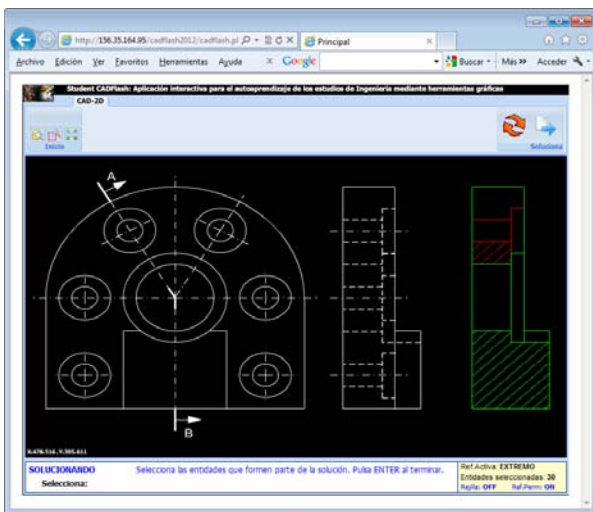

Fig. 2 Solving exercises with CADFLASH.

In this way, the centre of the learning process is the student himself or herself. CADFLASH allows the students to adjust their work schedules depending on their available time since they are not limited to the classroom work. The application wants the students to learn by themselves because only resumed contents will be taught in lecture classes. Besides, it is possible the Access to the Web application from any location, schedule, and operating system if the computer is provided with Internet connection.

In addition, there is a change in the functions of the teacher, taking now the role of guiding the student. The use of the interactive Web environment helps the teacher to correct the exercises, reducing the expenditure of time to this task. Therefore, the teachers can focus all their efforts on improving the quality of teaching the subject

and leaving the correction of the activities to the application.

B. Block II: Technical Drawing practices.

This second block is composed of 11 hours. The students will complete exercises corresponding to views, sections, dimensioning and representations of technical models using traditional drawing tools (paper, pencil and drawing utensils).

3.3   Laboratory practices

The student has five sessions of two hours to learn the fundamental 2D-tools of AutoCAD (draw entities, edit entities, object references, layers, blocks, dimensioning and print drawings).

The students know the tools of CADFLASH prior to beginning theses laboratory classes so in the first session, the teacher only teaches those elements which are different in AutoCAD. Anyway, the students need a brief period of adaptation to the new environment.

In the rest of the sessions, the students learn new tools (layers, blocks, dimensioning tools, model/paper space, print) to reach a level of knowledge that allows them to manage any 2D-CAD environment.

During these practices, a set of exercises are proposed to the students with the purpose of applying all the knowledge acquired. These exercises are carried out in mentee sessions with the presence of at least one teacher, so that they can solve all the doubts that may arise during their work.

3.4   Distance learning

A collection of exercises corresponding to all the materials studied in this subject is proposed so that the students can solve them out-of-class and improve the knowledge acquired in the classroom.

Some exercises complementary to laboratory practices are also proposed with the purpose of studying the use of the basic tools in CAD systems.

Therefore, the collection of exercises for distance learning is composed of 336 exercises divided into (Fig. 3): 144 exercises of dihedral representation system; 27 exercises of dimensioned drawing system applied to civil engineering; 45 exercises of axonometric system; 95 exercises of technical drawing and 25 exercises of 2D-CAD.
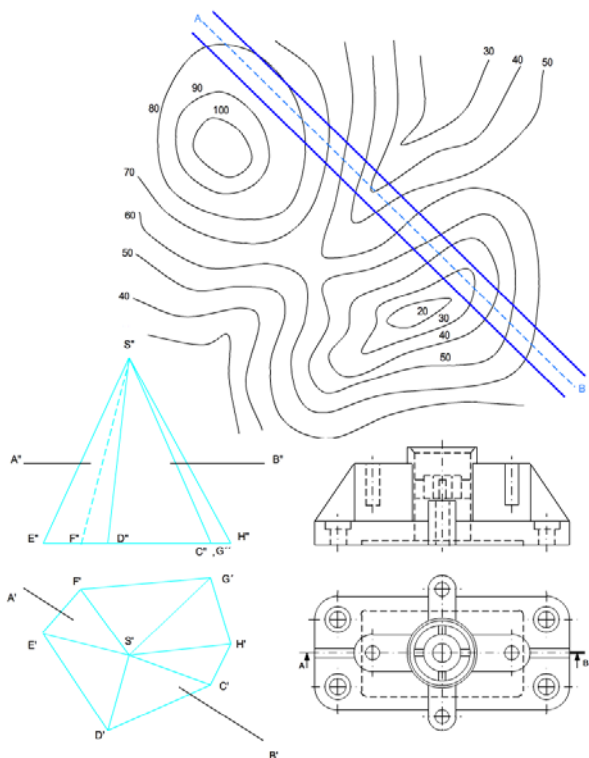
Fig. 3 Examples of exercises in CADFLASH.

4   Evaluation of the subject

The evaluation of the subject is continuous. The students have to pass some activities which are shown in tab. 3.

The CADFLASH exam, carried out in the computer classroom, consists of 10 exercises chose randomly from the collection available in distance learning. The weight of each topic (*dihedral representation system, dimensioned drawing system applied to civil engineering and axonometric system*) in the sample of exercises depends on the time assigned for each of them in the subject. The maximum time for completing the exam is 75 minutes. The results obtained are automatically stored in the database of the application and the teacher can see this information in real time during the exam or later to process it.

Activity	Percentage	Mark
CADFLASH exam (Descriptive Geometry)	20%	2 points
Traditional exam (Technical Drawing)	30%	3 points
Distance learning	30%	3 points
Laboratory practices	20%	2 points
Total	*100%*	*10* points

Tab. 3 Activities evaluated in the subject.

The traditional exam is carried out in the examination room. Using the traditional tools (paper, pencil and drawing utensils). It consists of a serie of exercises covering the most important aspects of the technical drawing (*views, sections and dimensioning of models*). The maximum time is two hours.

The non-contact work is valued automatically by CADFLASH, storing the results in the database for processing later. The database store datum such a as the mark of the exercises, the attempts carried out, the time spent on each one of them or the date when the exercise was passed. All this information is available in WORD or EXCEL format for its teaching and statistical analysis.

Finally, the evaluation of the laboratory practices is achieved through a test consisting of an exercise carried out with the tools available in AutoCAD and learned during the laboratory classes. The degree of similarity with the solution and the way in which are used the different tools of AutoCAD are the elements valued by the teacher to obtain the mark of these practices. The maximum time for this test is 60 minutes.

To pass the subject, the students have to reach 5.0 points over 10. Besides, they also have to get at least 50% of the mark in each of the four blocks in which the evaluation of the subject is divided. In this way, the student must have a minimum knowledge in each block.

5   Results obtained

42 students (of 73 enrolled) from the course 2010/2011 and 65 students (of 85 enrolled) from the course 2011/2012 have participated in this experience. It is interesting to indicate that the number of women participants in both courses has been stable, increasing only the number of men, as shown in tab. 4.

	2010-2011		2011-2012	
	M	F	M	F
Nº students	30	12	53	12

Tab. 4 Distribution of students per course.

The results obtained by the students in the two courses of the experience are collected in tab. 5. This table also show the values of the partial results obtained in each activity evaluated.

		Dist. Learn.	CADFLASH exam	Tech. Draw. exam	AutoCAD exam	TOT.
2010 - 2011	M	1.56	1.13	1.61	1.45	5.75
	F	2.08	1.08	1.27	1.64	6.07
	TOT.	1.71	1.12	1.51	1.50	5.84
2011 - 2012	M	1.76	1.37	1.54	1.53	6.20
	F	2.07	1.28	1.90	1.62	6.87
	TOT.	1.81	1.36	1.61	1.56	6.34

Tab. 5 Average marks obtained by the students.

As show tab. 5, the results obtained during the course 2010/2011 was somewhat lower than during the next course (5.84 vs. 6.34).

Analyzing this information separately, the average mark of the male groups (M) increases slightly in each of the activities evaluated during the second course, except in the exam of technical drawing where there is a minimum decrease in the results. By comparison, the average marks of the female groups (F) remains virtually

stable in both courses, except in the exam of technical drawing where there is an important increases in the results, which makes the total average mark up 0.8 points.

In addition to this data, it is interesting to point out that 34 students (23 males and 11 females) passed the subject during the course 2010/2011, equivalent to 80.95% of the total. In contrast, 58 students (47 males and 11 females) passed the subject during the course 2011/2012, an 89.23% of the total. Therefore, the pass rate is similar in both courses although the number of male students was increased substantially during the second course. The female pass rate is kept constant in both courses but there is a significant increase in the average marks of the course 2011/2012.

Interesting results were obtained analyzing the marks by numerical ranges (Fig.4 and Fig.5). The increase of students in the male groups during the course 2011/2012 brings along with it roughly proportional increase in the number of students grouped into each range of marks. That is, there are more students but the rate of them with the same range of marks is similar. However, there is a homogeneous redistribution of the results in female groups, obtaining a similar number of students in each mark range.
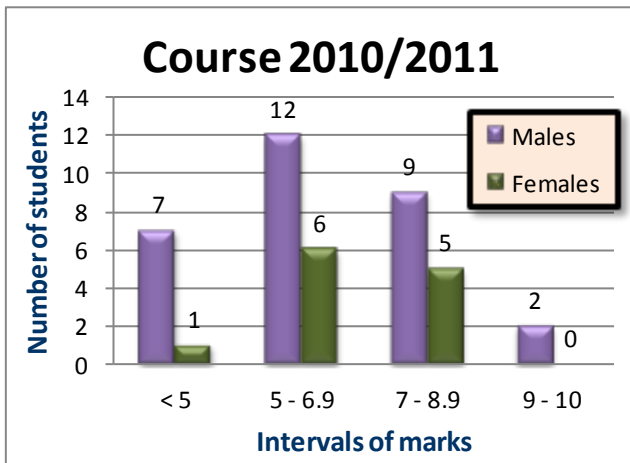

Fig. 4 Number of students by mark range in the course 2010/2011.
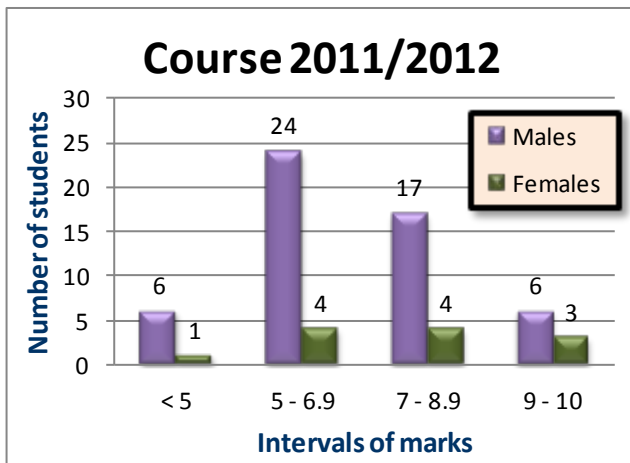

Fig. 5 Number of students by mark range in the course 2011/2012.

The work done by the students in the different materials of CADFLASH can give an idea of the time spent on each of them in the subject. Tab. 6 shows the average values of all these data, as well as the average percentage of the correct exercises in each topic available.

		2010-2011		2011-2012	
		M	F	M	F
DIHEDRAL	Nº EXERCISES	144			
	% SUCCESS AVERAGE	28.2%	40.0%	45.1%	51.5%
	AVERAGE TIME	7:53:04	13:50:26	14:11:07	14:04:23
DIMENSIONING	Nº EXERCISES	27			
	% AVERAGE SUCCESS	32.8%	42.2%	45.0%	54.0%
	AVERAGE TIME	4:29:22	6:18:55	6:49:40	6:34:54
AXONOMETRIC	Nº EXERCISES	45			
	% AVERAGE SUCCESS	21.2%	24.5%	39.7%	44.8%
	AVERAGE TIME	5:00:04	7:57:42	7:55:46	7:43:33
TECH. DRAWING	Nº EXERCISES	95			
	% AVERAGE SUCCESS	14.9%	29.7%	38.3%	45.2%
	AVERAGE TIME	6:02:18	11:45:57	10:20:32	12:40:02
CAD	Nº EXERCISES	25			
	% AVERAGE SUCCESS	52.0%	78.1%	15.7%	16.7%
	AVERAGE TIME	5:16:28	7:40:44	6:08:54	5:39:20
TOTAL	Nº EXERCISES	336			
	% AVERAGE SUCCESS	25.7%	38.1%	44.3%	50.8%
	AVERAGE TIME	28:41:16	47:33:44	45:25:59	46:42:13

Tab. 6 Results of the students in CADFLASH.

The first course of this experiment showed that the students focused too many efforts in the study of CAD tools but they were neglecting the study of the other topics. This situation caused different levels of knowledge in the materials studied. Ones this potential "trouble spot" was located, the course 2011/2012 was organized to

focus the efforts of the students to study Descriptive Geometry and technical drawing and decrease the work with specific exercises to study CAD tools. As tab. 6 shows, the work in dihedral representation system, dimensioned drawing system applied to civil engineering, axonometric system and technical drawing was increased during the second course of the experience, whilst the specific work in CAD exercises was decreased. This reason may be one of the causes for the average increase of marks obtained by the students.

If the time devoted in each topic grouped by males and females is analyzed, the first remarkable point is that the average time of the female is similar in both courses (it even decreased one hour during the course 2011/2012), varying only the effort distribution to each of the topics. The average time of the males increased considerably in the course 2011/2012 (17 hours) but the increase in results was not as important as in the female groups (0.45 of males vs. 0.80 of females). An appropriate distribution of time spent on each of the topics could solve the problem and allow to achieve better results.

6 Conclusions

The implementation of the European Higher Education Area brings, among others innovations, the change of the traditional teaching methodology, replacing it with other focused on the students and their personal learning work. For that reason, the contents and activities of the subject "Graphic expression" in the new grades of Engineering of the University of Oviedo were adapted for this new learning system.

In order to facilitate the transformation of the teaching process, a Web graphic application that allows the self-learning of the students was developed. This application combines tools usually existing in a 2D-CAD system with an automatic exercise correction system.

Thus, the teachers of the new grades take less time and effort to correct exercises and spend this time in guiding the individual learning of the student. Therefore, the teachers, using the Web environment described in this paper, devotes all their energy in monitoring student learning, which can lead to an improvement in the quality of the teaching.

In addition, problems of increasing difficulty based on the progress of the student can be developed with the purpose of designing different methods according to the particular needs of each one. The traditional methodology forces the teachers to adapt their classes to slower students. However, using applications such as the one described in this paper, each student devotes the time necessary in each situation, optimizing the effort because this type of application allows a total availability of both time and place for learning.

It is important to indicate that the proposal described in this paper allows the students to combine three different methodologies in their study: the traditional (manual drawing utensils in the classroom), the use of interactive tools for the self-learning (CADFLASH) and the use of professional CAD tools (AutoCAD).

According to the results obtained with this learning methodology and analyzed in this paper, the use of an interactive graphic Web application can directly influence the motivation of the students in the study of the subject. In addition, it can adapt its contents to the specific needs of the students depending on the capabilities and objectives to be achieve. This adaptation is quick and easy due to the application is provided with a GUI that is flexible and can be tailored to individual needs.

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