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The Influence of ICT on Learning in Graphic Engineering

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Abstract

As a result of the introduction of the European Higher Education Area, the inclusion of 3D geometric modelling tools of the parametric type in Graphic Engineering requires a new approach to both the theoretical and practical content of the field. This rethinking provides significant improvements in the teaching of spatial geometry, involves new activities both in and outside the classroom, and puts into practice new teaching-learning models.

This work addresses the influence on learning of Information and Communications Technology (ICT) in the new study plans for the Graphic Expression engineering degree courses imparted at the *Universitat Politècnica de Catalunya·BarcelonaTech, Escola Universitaria d'Enginyería Tècnica Industrial de Barcelona*.

The advantages arising from the improvements in model displays and the understanding of problem statements and their solutions mean that time can be saved in theoretical explanations. Theoretical lectures, which have traditionally been regarded as indispensable when teaching systems of representation and methods of two-dimensional drawing, can now be partially replaced by an increasing use of practical sessions in Computer-Aided Design.

The results show that the inclusion of ICT leads to a notable improvement in academic results and in student satisfaction with the subject studied.

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Keywords: Graphic Engineering; Learning; Graphic Design; Assessment.

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1. Introduction

With the introduction of Computer-Aided Design (CAD) into university education, as set out in the *Boletín Oficial*

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del Estado (BOE, 1992) for the 1993 study plan, the use of computer programmes was intensified as part of the teaching of Graphic Expression (GE), while at the same time Information and Communications Technology (ICT) was also taking root in higher education. The inclusion of ICT makes it possible to conduct new activities in the classroom as well as new ways of organizing teaching and study time and space. In addition, new learning models appear as an alternative to physical attendance in the classroom, such as the purely virtual and hybrid or blended learning models (Heinze & Procter, 2004), all of which means that classes are no longer merely an expositive exercise for teaching staff.

Teaching activities with student participation are organized in CAD laboratories where members of the teaching staff act as moderators. They thus not only provide explanations of course contents and instructions, but also facilitate and guide the learning process by increasing personalized attention for each individual student. Computers by themselves do not change anything; rather it is the teaching staff who change the approach to learning and adapt it to meet the challenges of the new model arising from ICT.

The Spanish Organic Law governing Universities (LOU) 6/2001 of December 21st, 2001 (BOE, 2001), stipulated that the Spanish Government would introduce the necessary reforms for convergence towards the European Higher Education Area (EHEA). In February, 2003, the Spanish Ministry for Education, Culture and Sport published the Framework Document "Integration of the Spanish university system within the European Higher Education Area" (Ministerio de Educación Cultura y Deporte, 2003). In this document the government stated that the inclusion of ICT in the Spanish university system was essential for full compliance with the new EHEA, and among others also made the following recommendations: 1) To incorporate ICT into post-graduate courses (at the very least). 2) To provide partial face-to-face and as well as university courses not requiring on-campus attendance. 3) To provide courses that do not require physical presence in the classroom. 4) To stimulate a conceptual change in teaching staff toward learning more focused on each individual student. 5) To create new courses before remodelling the existing traditionally designed courses. 6) To set minimum standards of quality for courses not requiring attendance on campus. 7) To assess such courses in a manner equal to or greater than face-to-face courses.

On the basis of these recommendations, all the GE courses in Spain include the three descriptors that the Ministry of Education publishes with regard to this subject: 1) Systems of representation. 2) Standardization of industrial design, and 3). Computer-Aided Design. In the 46 GE programmes (43% of the GE subjects detected) (Farrerons & Olmedo, 2016), a very similar syllabus is applied in the different Spanish universities: Introduction to industrial design; introduction to CAD; basic concepts of standardization; systems of representation; computational geometry; geometric primitives, and constructive geometry of bodies and surfaces.

In April 2008, the *Universitat Politècnica de Catalunya·BarcelonaTech* (UPC) approved the document "*Marc per al disseny i la implantació dels plans d'estudis de grau*" ("Framework for the design and implementation of degree study plans"), which includes a series of methodological and assessment guidelines that should be taken into account by university academic staff (UPC. Consell Social, 2008). It also provides for the introduction of seven generic competences in all the degree courses, where the way in which these competences can be included in the study plans in order to ensure their acquisition by students. The model based on the competences imparted at the UPC has its origin in the Tuning Project (Tuning Educational Structures in Europe) (González & Wagenaar, 2009) and was developed with the aim of introducing the process arising from the Bologna Declaration into Spanish universities.

This process of adaptation to the European Higher Education Area (EHEA) undertaken at the UPC (Torra et al., 2010) includes in its curricula innovatory educational models, training in generic and key skills competences, and new teaching-learning methodologies. The study plans aimed at the successful completion of university degree courses should therefore focus on the learning and acquisition of the competences and qualifications in each subject as well as on assessment strategies that verify such acquisition. These competences are specific and correspond to training in both generic and key skills that are focused on the development of individual skills, all of which is included in the credit hours stipulated for that purpose.

Planning for the new degree courses involve three key factors: a) learning centred on the student; b) the achievement of goals based on skills and planning; c) student assessment, and d) planning for face-to-face and non face-to-face activities by means of the European Credit Transfer System (ECTS) (ICE, Institut d'Ciències de l'Educació - UPC, 2008). From this perspective, the academic staff designs learning activities based on the objectives to be achieved, guides students throughout the learning process, and finally applies an assessment strategy to enable the students acquisition of competences to be measured. Furthermore, students undertake the planned activities, construct and participate in their own learning and even in their own assessment (self-assessment or assessment among equals).

All the evidence for assessing student acquisition of the skills is gathered by tools that associate the knowledge acquired with the use of the new technologies, as proposed in ("*Marco de cualificaciones del Espacio Europeo de Educación Superior,*" 2002), (Criterion 3. Program Outcomes and Assessment, 2003) and (QAA. The Quality Assurance Agency for Higher Education, 2002). The assessment strategies employed help students to acquire the generic competence through autonomous learning (the generic competence that is compulsory in this subject).

On the basis of the 1995 study plan, the subject known as "Technical Drawing" is now referred to as "Graphic Expression and CAD)" (GECAD). This subject is divided into three types of educational credits: Theory, Practice and Laboratory. From an approximate total of 500 enrolled students each year, the class groups consisted of 120 students. There was a one-hour Theory class per week in which students listened to a lecture on the industrial standardization of technical drawing. These 120 students were then divided into two Practice groups consisting of 60 students in each group. In these practical sessions, technical drawing was taught with the multiview orthographic system in which problems in this system were addressed; sets of mechanical parts, freehand sketching, scaled drawing in the European system of first angle projection, projected views, sections, dimensions and so on, as well as drawing with fountain pens. Finally, each group in the practical class was divided into 4 laboratory groups (15 students per group) with a two-hour CAD class every two weeks. Class time varied according to the speciality: Mechanical Drawing (5 hours of class per week), 3 hours of Theory, 1 hour of Practicals, and 2 hours of Laboratory every two weeks. The remaining specialized subjects (Chemistry, Industrial Electronics and Electricity) consisted of 4 hours of class per week (2 hours of Theory, 1 hour of Practicals, and 2 hours of Laboratory every two weeks). The grades for the subject are arrived at through a final exam on industrial standardization (drawing of views and axonometric projection, 50 %), multiview orthographic (25 %) and Laboratory (25% with three mid-term exams).

The degree subject GE at the UPC Engineering of the *Escola Universitaria d'Enginyería Tècnica Industrial de Barcelona* (EUETIB) was finally defined in 2010 and ICT has played a decisive part in the improvement process of this compulsory subject that consists of 6 ECTS credits and is imparted in the first quarter of all degree courses (Electrical Engineering, Mechanical Engineering, Chemistry, Industrial Electronics, Biomedicine and Energy).

The aim is to demonstrate that the introduction of ICT and the improvement in the teaching methodology based on teaching objectives defined for self-study, CAD objectives, combined knowledge and key skills objectives, have brought about a considerable improvement in the academic results of students. Furthermore, it is shown that by combining explanatory and self-learning theoretical classes, together with corrections based on rapid return rubrics (Martinez, Olmedo, Amante, Farrerons, & Cadenato, 2014) have reduced the weekly workload on students.

2. Aims

The main aim is to analyze the influence of the introduction of ICT into the teaching-learning process in the GE subject.

The main changes in the teaching methodologies and assessment strategies arising from the plan mentioned above are hereby presented as the specific objectives.

In order to verify the main specific objectives and to check the degree of student satisfaction with the assigned course, an anonymous online survey was carried out with the participation of 200 students during the academic years 2013 and 2015.

This survey will prove useful for teaching staff and researchers who wish to implement effective methodologies for teaching subjects related with design and graphic expression and for the application of highly useful tools for the learning and assessment processes, not to mention innovations concerning the student teaching-learning process (Voltas, Marqués, Lapaz, & Bermúdez, 2011).

3. Method

For the GE subject, the generic competence through autonomous learning is acquired by means of continuous assessment of standardized knowledge, industrial design and spatial geometry. The formative objectives reach level 1 of guided learning and are assessed according to whether the time taken by students to solve the problem is correct; if they way in which they have done this has also been the right one, and if there has been any reflection on the applicability of the content. The assessment system is based on criteria of quality (Urraza & Ortega, 2009) and on teaching innovation (Cadenato, 2012), thereby establishing a strategy of continuous assessment. All the assessments come with a quality public rubric from the beginning of the course (Cano, 2015). Assessment is of a formative and summative nature and the feedback for the assessment activities is done on a weekly basis (Pastor, 2011).

The final mark for the subject is expressed in the following formula:

$$\text{FINAL MARK} = 0{,}05\times 1^{er}P + 0{,}2\times 2^{do}P + 0{,}15\times 3^{er}P + 0{,}06\times C + 0{,}06\times EE + 0{,}28\times EP + 0{,}2\times Proy$$

Where:
$1^{er}P$ = 1^{er} Midterm exam, $2^{do}P$ = 2^{do} Midterm, $3^{er}P$ = 3^{er} Midterm, C = Sketch book, EE = Tutorials, EP = Questionnaires, Proy = Project

An anonymous, online survey is conducted using Google Drive® questionnaires in order to gauge the evolution of student satisfaction in the implementation process of the new study plan for the subject. The SEEQ-type survey (Students' Evaluation of Educational Quality) (Victoria, Matés, & Cal, 2010), which is highly effective as a tool for teaching assessment, is based on aspects concerning interest in the subject, understanding of the contents, the effectiveness of work groups, and the methods and means of formulating the assessment, among others. The possible responses take the following form: Agree very much; Agree; Disagree; Disagree very much.

The survey was given to 200 students belonging to different groups of the subject in two different years: three years after the introduction of the new study plan (2013, 108 out of a total of 332 enrolled students) and two years after that (2015, 92 out of a total of 325 enrolled students).

Reliability tests were applied (Cronbach's Alpha, two Guttman split-halves and the intraclass correlation coefficient) to determine the reliability of the questionnaire and resulted in optimum indexes. This is a simple random probability sample with a heterogeneity of 50%, a level of confidence of 95% and a 50% margin of error.

This research falls within the framework of the quantitative paradigm and employs a non-experimental, descriptive methodology. The validity of the tool is determined in terms of the validity of the construct and the criterion, and was subject to appraisal by a panel of experts who are researchers at the *Universitat Politécnica de Catalunya* (Technical University of Catalonia) and the *Universidad Nacional de Educación a Distancia* (National Open University).

The aim of the survey is to verify the main objective of this study (improvements in the teaching-learning process) as well as the specific objectives (the assessment strategies employed in the acquisition of the generic competence of autonomous learning).

The data gathered serve to improve the evaluated process (formative assessment) and to approve the quality of this process (summative assessment), as set out by (Marsh, H., & Roche, 1970) and (Corral, I. Almajano, M. & Domingo, 2010).

4. Results and discussion

Previously to 2010 the academic results were very dissimilar. 90% of students obtained the Laboratory credits and 75% standardization, while only 30% did so in multiview orthographics. The total number of passes was approximately 50% of enrolled students and varied according to the speciality. More students passed in Mechanics than in Chemistry, which was the subject with fewest passes.

In 2010, the modifications in the study plan improved the theoretical and practical performance and led to better academic results. Improvements in teaching methodology are based on the strengthening of spatial conception; a deeper knowledge of geometric shapes as well as presenting, interpreting and practising the normative theory of the techniques of graphic representation most commonly used in engineering.

The contents of the GE course are defined according to specific learning objectives:

1. Self-study: Grouped according to content type where the theoretical content that should by learned by students is defined. Students are set 140 specific goals for self-study; they are grouped by sessions with bibliographical references for each goal. Students must prepare for these goals, convey their doubts to the teacher and expound the topic to the other members of their group. These goals are assessed through the specific competences of knowledge and understanding.

2. CAD: To be achieved by exercises that should be done both in and outside class by following multimedia tutorials. They are assessed through the specific application competence.
6 goals are identified for CAD: a) Apply the basic modelling techniques: 2D Sketch, base, outgoing, cutting, modification, section visualization. B) Apply the basic techniques of assembly modelling. C) Apply techniques of drawing constructive planes: editing format and template, adding standard views. D) Put into practice techniques for modelling surfaces. Creation of primitive surfaces by displacement (revolution, extrusion and sweep), coverage (covering wireframe models) and derived surfaces (generated from existing surfaces). e) Perform Boolean operations for editing surfaces: union, subtract, extension, etc. f) Concept of bi-parametrized surfaces and isoparametric lines.

3. Combined knowledge: Require the application of theoretical knowledge and practical skills. 14 goals are identified, combined with different specific competences.

4. Knowledge of key skills: This is an application skill consisting of a practical assignment carried out by working in groups (Group Project). It fosters the formation of students are who specialists in some theoretical aspect and applies the puzzle technique for promoting learning among equals.

The assessment strategies employed are as follows:

1. Self-learning of theoretical concepts: The cooperative training puzzle technique is used (Aronson, E., Blaney, N., Stephin, C., Sikes, J., & Snapp, 1978) according to the innovations in learning methodologies (Roca, Reguant, & Canet, 2015) and (López Pastor, 2012) with groups of 3 students.

2. Sketching exercises: This is an individual assignment, although guided correction in groups is highly recommended for individual correction of sketches prior to being handed in.

3. CAD tutorial exercises: These are completed outside the classroom and consist of tutorials on the programme used in GE, SolidWorks Education Edition®. Students are required individually to complete a guided exercise, and once it is finished they send it in via the Virtual Campus before the start of the next class. These exercises are undertaken in the manner of a blended learning model.

4. Problems in CAD: CAD is not only a tool for drawing. It also enables a 3-dimensional object to be created, moving from the drawn object to the constructed object and vice-versa. 4 types of exercise are proposed: 3D modelling on the basis of multiview orthographic projection, 3D modelling and planes from an axonometric projection, exercises of spatial geometry and the geometry of surfaces.

5. Project: This is based on techniques of cooperative and constructivist learning (Morato Moreno M., 1999) and consists of completing and delivering an original project consisting of different mechanical components undertaken by groups of between 3 and 4 students.

The survey of the evolution of students satisfaction in the implementation process of the new study plan for the subject show that 66% of students agree (85% agree or agree very much) that they have learned and understood the contents of the course. It is observed that this percentage has increased by 25% between the years 2013 and 2015. Students state that 58% (71% agree or agree very much) that the classes have been very clear and have helped them to understand the subject. An increase of 18% is also observed from 2013 to 2015. The overall results of the survey (2013 and 2015) show that 78% agree (89% agree or agree very much) that the approach adopted to assess the course has helped them to understand the academic contents better, and that the assessment methods for the course are both fair and appropriate (61% agree and 81% agree or agree very much) (Fig. 1. a and b). These results show that the practical introduction of the learning-teaching methodologies and the assessment strategies employed have been useful and effective for students in the acquisition of the self-learning generic competence. A notable improvement is likewise seen in the results over the two years following the first survey.

62 % of students state that the course did not require a much greater effort when compared with other courses, while 25% say that it was relatively easy to complete the course. It is further verified that a high percentage of students observed a fall in their weekly workload.

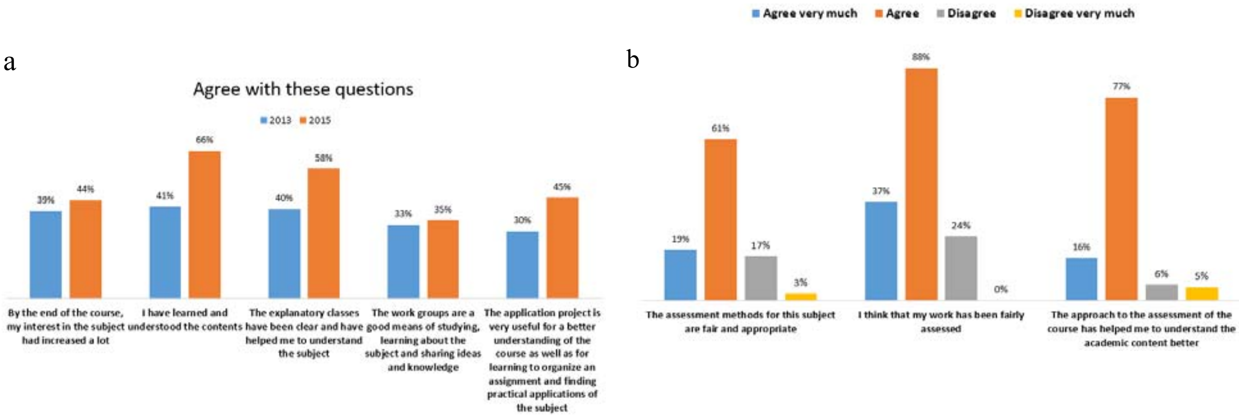

Fig. 1. (a) Students agree with some questions concerning the GE course for the years 2013 and 2015; (b) Student satisfaction to questions concerning the GE course.

These results can be quantified by the final marks achieved in the subject, 80% of which are passes and which are considerably higher than those attained before the application of the methodology herein described (approximately 50%). Of the activities undertaken in the classroom, those forming part of the assessment are the ones which to the greatest extend condition learning, since they are at the heart of this process.

With the current approach to the subject, and together with the introduction of CAD, more emphasis is given to reducing the time devoted to theoretical explanations about systems of representation and two-dimensional drawing methods in favour of an increase in practical activities with digital tools. The advantages arising from improvements in model displays and in the understanding of statements and solutions enable the time devoted to theoretical exposition to be reduced. The explanatory sessions/lectures on systems of representation and two-dimensional drawing methods thus give way to an increase in practical sessions on Computer-Aided Design.

The teaching methodology applied has led to an improvement in the level of knowledge of graphic engineering by a closer involvement of students in the subject. The work carried out using CAD tools has enabled students to acquire the specific competences required in the face-to-face sessions. CAD constitutes an increase in the set of methods for geometric modelling to complement the systems of representation used in two-dimensional supports. Despite the implementation of new procedures based on modelling using 3D CAD systems, maintenance of the orthographic projection system is observed as theoretical reasoning and an instrument of abstraction.

ICT has helped to facilitate the change in the teaching-learning methodologies proposed in the EHEA framework, in which students have been some of the influential actors in the transformation in the field of Graphic Engineering, thanks to the interest that the new technologies have aroused in them.

The computerization of teaching has brought about an improvement in the management and academic monitoring of the subject, thereby automating these tasks of monitoring and management by making them much quicker and more effective. Stimulated by the use of ICT, the projects for improvement and innovation in teaching have evolved towards virtual learning spaces in which students are provided with a learning process adapted to their individual needs.

5. Conclusions

The incorporation of ICT has given rise to a rethinking of the theoretical and practical contents of the subject, which has led to advances in the teaching of spatial geometry, the introduction of new activities both in and outside the classroom, and new teaching-learning models. Furthermore, ICT has brought about an increase in the academic results and student satisfaction with the subject.

In addition, the advantages derived from the improvement in model displays and the understanding of problem statements and solutions are also clearly evident, thereby enabling the time spent on theoretical exposition to be reduced. The explanatory sessions/lectures on systems of representation and two-dimensional drawing methods have been partially replaced by an increase in practical classes using Computer-Aided Design.

Taking into account the didactic characteristics of the new formative proposals, we have been able to contribute to the changes in the teaching methodology for the learning of graphic engineering as taught at the EUETIB.

This methodology can be applied to other areas where the technological component has a considerable influence on the corpus of the subject.

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