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Detection of Training Deficiencies in the Autonomous Learning of Graphic Engineering Students: A University Teacher Training Experience Based on Competencies

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The Universitat Politècnica de Catalunya·BarcelonaTech (UPC) offers a postgraduate teacher-training programme based on "Science, Technology, Engineering and Mathematics (STEM) postgraduate university teacher-training" competencies consisting of 15 ECTS, which officially began in September 2015. This Postgraduate course concludes with a final project carrying 6 ECTS in which students are required to design and plan an innovation in teaching to implement in the classroom and to analyse the results; this project is supervized by a senior female lecturer from the university with experience in teaching innovation. This article presents a final project that consists in planning different voluntary activities with the aim of increasing the level of acquisition of the autonomous learning generic competence of students engaged in Graphic Expression (GE). This is a core subject in the first year of all the engineering degree courses imparted at the UPC *Escola d'Enginyeria de Barcelona Est* (EEBE—Barcelona East School of Engineering). This set of activities will continuously generate a series of outcomes to provide students with formative feedback, thereby enabling them to detect deficiencies in the goals established for the subject and make improvements in good time. The results of these outcomes are then analysed and related to the compulsory assessments that are taken into account for the final evaluation of the said generic competence. Participation in these voluntary activities fosters the acquisition of the autonomous learning competence and contributes to a notable improvement in the teaching-learning process of spatial geometry. Furthermore, this postgraduate teaching innovation project has allowed the participating lecturer to apply the acquired competencies to the different subjects, which has resulted in improved student learning as well as enabling a senior female lecturer to advise another female faculty member of the same university by sharing her experience, which in turn has enriched the teaching experience.

Keywords: assessment tools; competencies; autonomous learning; engineering degree; graphic engineering

1. Introduction

Many teachers take up their careers in universities without any special training to prepare them for their tasks as lecturers. This sets university teachers apart from other professional collectives who are required to undergo training and preparation prior to undertaking their professional responsibilities. While many universities provide training courses for new teachers, such courses are always voluntary, and although few teachers take them evidence shows that those who do are usually the ones who are most interested in lifelong learning [1]. Despite the lifelong learning and mobility programmes available for educators, teachers at technical universities are sometimes reluctant to take advantage of these types of training courses because they rarely help them to achieve promotion.

The opinion held by each teacher of his or her own teaching is substantiated by student opinion in surveys conducted at the end of every course, and it is this belief that guides their work, which over time becomes fixed, unvarying and resistant to change. In this way, if teachers themselves feel no dissatisfaction with the way they teach then it is very difficult to change.

The training of university teachers has in recent years been the subject of research [2–4] that has focused on the methods and tools needed in order to achieve quality teaching practice. Improvements in the quality of teacher training require a combination of three factors: research in order to find personalised teaching methodologies; creative and innovatory practices for teaching, and national initiatives to enable engineering schools to make the necessary organisational changes to support teaching and learning more effectively [5].

A global study describes the ideal profile and characteristics of a teacher of engineering:

1. He or she is competent in his/her own discipline and in the solving of problems.
2. He/she conducts research, publishes papers, communicates effectively and upholds an enterprising spirit.
3. Facilitates learning by using student-centered

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strategies, keeps abreast of the advances in engineering education, applies studies and cases, is concerned for students and their learning and enjoys being a mentor.
4. Understands the role of his/her profession in society, practices it as part of the development of his/her own career, participates in forums to promote the formulation of policies and excellence in education, research and innovation.
5. By means of practice and experience develops the competencies that engineers must possess, the better to serve society and become a worthy role model for students [6, 7].

The paradigm shift in university teacher learning is already taking place. Incorporation into the European Higher Education Area (EHEA) means that learning based on content is moving towards learning based on competence [8–11]. Thus, it follows that teacher-training should also be based on competencies.

The 2010 European education and training initiative (ET 2010) [12] established a strategic framework for European cooperation in the field of education and training until 2020. Some of its main objectives were lifelong learning, mobility, and a system of education and professional training more in tune with change. Furthermore, it promoted improvements in the quality and effectiveness of education and training; social equity for the ongoing development of lifelong professional skills, and creativity and innovation at all levels of education and training, since they are the main driving forces in sustainable economic development.

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 introduction of degree study plans''), in which a series of methodological and assessment guidelines are set out for current university degree qualifications [13], as well as the introduction of seven generic competencies in all degree qualifications and the way in which these competencies can be incorporated into the study plans to ensure their acquisition by students. The competence-based model employed by the UPC originates in the Tuning Project (Tuning Educational Structures in Europe) [14] and was developed with the aim of introducing the process that followed the Bologna Declaration into university education.

In the process of adaptation to the EHEA undertaken by the UPC [15], innovative educational models are incorporated into its curricula as well as training in generic or transversal key competencies and new teaching/learning methodologies [16]. The objectives of study plans that lead to the acquisition of a university degree should therefore be focused on the learning and acquisition of the competencies belonging to each subject and qualification, and also on the assessment strategies for verifying that acquisition. These competencies both generic and transversal are specific to the training and thus more focused on the development of individual skills, all of which should be included in the credit hours established for that purpose.

The spirit of innovation and the ability of teachers to plan and undertake innovation constitute one of the essential competencies required by university teachers, especially in the context of the reforms necessary to satisfy the requirements and expectations set out in the construction of the EHEA project.

Planning for the new university degree courses consists of four essential elements: (a) Student-centered learning, (b) achievement of goals based on skills and planning, (c) student assessment, and (d) planning of classroom and distance-learning activities using the European Credit Transfer System (ECTS) [17]. With this in mind, the academic staff designs learning activities based on the training objectives to be achieved, guides students through the learning process, and finally applies an assessment strategy for measuring students' acquisition of the competencies. Furthermore, students themselves carry out the planned activities, construct and participate in the learning process as well as in their own assessment (self-assessment or assessment among equals).

The ways in which the different institutions implement good teaching practice depend largely on their students and their circumstances, where what is taught is less important than how it is taught in accordance with the seven principles of teaching quality [18].

In 2011, the *Grupo Interuniversitario de Formación Docente* (GIFD—Inter-university Teacher Training Group) (http://gifd.upc.edu/), to which the UPC *Institut de Ciencies de l'Educación* (ICE—Institute of Educational Sciences) (http://www.ice.upc.edu) belongs, conducted a study in which it was concluded that university teachers should possess the following six competencies: Communication, Interpersonal Relations, Teamwork, Innovation, Planning and Management of teaching, and Methodology [1].

On the basis of these six competencies required by university academic staff, the ICE of the UPC has designed and developed a teacher-training, competence-based programme known as a University Teacher Postgraduate Course in ''Science, Technology, Engineering and Mathematics'' (STEM), a qualification awarded by the *Fundació Politècnica de Catalunya* (FPC), which officially began in September 2015.

Table 1. Courses that make up the block of basic or core subjects. Source: ICE-UPC.

Subject	Student hours per course (Total Nº of hours: class attendance, distance learning and tutorials)	Competencies					
		Communicative	Interpersonal relations	Teamwork	Innovation	Teaching planning and management	Methodological
Design of competence-based subjects	17	6	4	4	4	17	
Can I actively update my teaching methodology?	25	1		2	2	2	20
Teamwork theory and practice	13	3	3	13		2	
Teaching innovation; what it is and what it's like	8				8		2
Social skills training	25	2	15		3	3	3
Teaching communication	19	10	1	4		2	
Methodology for developing an innovation in STEM	18	4	2	4	8	2	2
Total hours for the compulsory part	125	26	25	27	25	28	27

The aim of this postgraduate course is to enable lecturers to acquire a series of competencies as well as the tools to apply innovative methods in the teaching of technology and engineering, attaining thereby a high standard of teaching practice.

This postgraduate course carries 15 ECTS (European Credit Transfer and Accumulation System) credits divided into 6 credits corresponding to the acquisition of the six basic or core competencies over 7 subjects, 3 credits corresponding to complementary or elective training, and 6 credits for an innovatory teaching project in which the set of six competencies acquired during the course must be applied [19]. Table 1 shows the subjects that make up the block of basic or core subjects, in which the classroom hours are specified, as well as classroom, distance-learning and tutorial hours for each of the six competencies.

The innovatory teaching project requires 150 study hours and a minimum dedication of three semesters, the object of which is to solve an identified problem and apply the solution to different groups of students in the classroom. The project should be submitted in the form of a report that is also presented publicly before a panel consisting of three members of the UPC academic staff who are experts in the subject.

Five of the six competencies acquired during the course are applied for the completion of this innovation project (Table 2); the teamwork competence is not applied, because only one lecturer from the faculty team responsible for the subject participated.

One of these innovation projects, completed by a participating female teacher during the 2016–2017 academic year and tutored by a senior female lecturer from the UPC, is presented in this article. This project forms part of the Graphic Expression (GE) subject and its aim is to improve the solution of problems using the CAD tools, to consolidate the theoretical concepts of the subject, and to enhance the quality of a final project by proposing voluntary activities that enable the level of acquisition of the autonomous learning generic competence (the competence assigned to the subject) to be raised.

2. Methodology

GE is a compulsory subject carrying 6 ECTS credits and is imparted during the first term to approximately 700 students in all engineering degree courses (Electrical Engineering, Mechanics, Chemistry, Industrial Electronics, Biomedicine, Energy and Materials) at the UPC *Escola d'Enginyería de Barcelona Est* (EEBE) [20]. The class groups (24 in total) consist of 30 students in morning (M) or afternoon (A) sessions.

Students are required to devote 150 hours to this subject (60 classroom hours and 90 distance-learning hours). Classroom hours are divided into 3-hour sessions in which 1 hour is devoted to theory

Table 2. Relation between STEM postgrad subjects and competencies with the application of the innovation project

Competence Subject (hs)	**Application of subjects to the innovation project**
Teaching planning and management Design of competence-based subjects (17h)	Design and planning of activities for the acquisition and evaluation of the autonomous learning competence assigned to the GE subject.
Methodological Can I actively update my teaching methodology? (20h)	Development of different formative continuous assessment activities to provide in-time feedback to help student autonomous learning.
Interpersonal relations Social skills training (25h)	Development of practical activities to facilitate teacher-student relations during the course. Increase student motivation through continuous feedback and dialogue with students. Detection of deficiencies in learning and recognition of student progress.
Communicative Teaching communication (19h)	In-class and online communication throughout the project. Development of innovation project in the form of reports or communications.
Innovation Teaching innovation; what it is and what it's like (8h) Methodology for developing an innovation in STEM (8h)	Identification of any learning/teaching problems and acquisition of information for solving any such problems. Propose innovation to take into class with the aim of solving any problems detected. Describe the said innovation in the form of an article or scientific communication.

and 2 hours to problem-solving. Classroom attendance is completed by 1 hour of teacher-directed activities (DA). Distance-learning study consists of both individual work and working as part of a team. The teaching methodology is based on strengthening spatial conception, extending knowledge of geometric shapes, and presenting, interpreting and practising the standard theory of the techniques of graphic representation most commonly employed in engineering [21].

GE is assigned the autonomous learning generic competence assessment that is acquired through different activities: theoretical exams, problem-solving and the completion of a final group project during the acquisition of knowledge regarding standardisation, industrial design and spatial geometry, on the outcomes of which the competence is assessed, together with the specific competencies of the subject. This key transversal competence is rated as level 1 in complexity according to the definition assigned by the UPC to the University's own key competencies [22]. This level of complexity evaluates whether students solve the problem or complete a given assignment within the time envisaged, whether they have done so in accordance with the guidelines, and if they have used the sources of information recommended by the teacher.

The assessment is continuous and formative and takes into account both classroom and distance learning in all the compulsory training activities, the feedback from which will enable students to determine whether they are acquiring the associated concepts in a continuous manner. The subject involves neither a final exam nor reassessment [23, 24].

The final mark for the subject is calculated according to the following formula:

FINAL MARK = 0.1xDAO1 + 0.25xDAO2 + 0.15xDAO3 + 0.1xPCA + 0.15xTTN + 0.1xTTG + 0.15xProy

Where:

Evaluation tests of theory in class:

TTN = Drawing norms self-assessment test
TTG = Self-assessment spatial geometry test
PCA = Mid-term sketching and adjustments

Evaluation test of problems in class:

DAO1 = 1st Mid-term exam. Making of parts and drawing.
DAO2 = 2nd Mid-term exam. Making of parts, drawing and assembly of parts.
DAO3 = 3rd Parcial. Spatial geometry.
Proy = Final group project. Distance learning.

The mark for the autonomous learning competence includes the weighted sum of the following activities: Project 65%, TTN 15%, TTG 10% and PCA 10%. This autonomous learning result is the one that should be compared with the voluntary activities carried out in this innovation project.

2.1 Objectives, context and planning of the innovation

An activity planning experience was designed with its corresponding outcomes through the Atenea virtual campus (atenea.upc.edu) in order to facilitate the acquisition of the autonomous learning competence. The activities themselves consisted of voluntary non-attendance-based activities as well as those that were compulsory.

These planned activities were carried out during the 2016 autumn term (1st quarter) in two of the groups (M32 and M61) from the 24 groups belonging to the subject. Group M32 consisted of 31 students and group M61 of 29 students.

The purpose of introducing these extra voluntary activities was to facilitate the acquisition of the autonomous learning competence in an integrated way with the competencies specific to the subject. This is expected to improve problem-solving with CAD (Computer-aided Design) tools as well as the acquisition of theoretical concepts, which in turn will lead to better results in mid-term exams and an improved performance in the final group project. While these activities do not form part of the summative assessment of the subject, they do reflect the attitude and willingness of students to undertake them. These activities are as follows:

Activity 1. Voluntary self-assessment theory test (EP).
Activity 2. Voluntary exercises prior to mid-term exam DAO3.
Activity 3. Learning based on examples or tutorials (EE).

Table 3 shows the planning for the three voluntary activities throughout the course, together with the compulsory assessments of the course.

Activity 1. Voluntary self-assessment theory test (EP):

Nine multi-choice self-assessment tests were planned to be done via the university virtual campus on an individual and voluntary basis. Specific objectives were assigned to each test so that all the nine tests covered all the objectives established for the subject. The tests consisted of questionnaires containing 6 questions chosen at random from a question bank; the answers were also ordered randomly and the maximum time for submitting the questionnaire was 10 minutes. Each question had four possible answers and a single correct solution; any question answered wrongly

Table 3. Schedule of compulsory and voluntary assessment activities

	Voluntary Activity Assessment			
Week	**Activity 1. Theoretical voluntary self-assessment test (EP)**	**Activity 2. Voluntary exercises**	**Activity 3. Example-based learning (tutorials) (EE)**	**Compulsory activities assessment**
2	EP 21. Norms, lines, scales and views		EE11. Getting started. Parts	
3	EP 31. Dimensions		EE23. Assemblies and Drawings	
4	EP 41. Cuts and cross sections		EE43. Revolves and Sweeps	
5			EE51. Advanced Drawings. Drawing Views	Mid-term DAO1
6	EP 61. Threaded elements		EE63. Advanced Drawings. Documentation	
7	EP 71. Conicity, surface finishes and dimensional tolerances		EE73. Advanced Drawings. Assemblies	
8	EP 81. Geometric tolerances and settings		EE83. Lofts	
9	EP 91. Standardized elements		EE93. Pattern Features	Mid-term PCA
10			EE101. 3D Sketching	Mid-term DAO2 and TTN Test
11	EP 111. Spatial geometry		EE112. 3D Sketching with planes	
12	EP 121. Metrics and geometric synthesis	Voluntary exercises	EE122. Assembly Mates	
13	EP 131. Surfaces		EE132. Surfaces	Mid-term DAO3, Test TTG Test Project

carried a penalty. Each correct answer was worth 0.5 punts, 0.3 points being deducted for an incorrect answer, so that the maximum score was 3 points and the minimum –1.5 (0 in the official score). Students could leave questions unanswered, in which case points were neither added nor subtracted. The tests were to be completed outside of class hours, and only two attempts were allowed with a delay of 30 minutes between attempts. The system did not provide the correct answers on completion of the tests, but the students were informed of the scores they obtained. These tests served only as a guide for students, who were expected to find the correct answer in the recommended bibliography or to consult their teachers outside of class hours.

Activity 2. Voluntary exercises prior to mid-term exam DAO3:

Assessments from previous years showed that the mid-term DAO3 exam (Spatial Geometry) constituted the most complex challenge and the exam that most students failed out of the three mid-term exams on the subject. As a means of incentivising students to improve their results in the last mid-term exam, they were given the opportunity of doing two alternative exercises using the SolidWorks Education Edition® tool one week before this exam. Teachers provided students with two exercises of medium to high difficulty via the virtual campus, to be completed individually outside of class hours and submitted before doing the mid-term exams. These completed exercises were worth two points (one point for each) to be counted towards the final result of the DAO3 mid-term exam.

Activity 3. Learning based on examples or tutorials (EE):

In order to improve practical skills in the making of parts, students were provided with support material or tutorials from the SolidWorks Education Edition® programme. These tutorials explain the functionality of this software in a learning format based on examples (12 in total). With these materials, students find it easier to learn how to use the software and develop techniques involving design, simulation, analysis and presentation. The students were required to study these tutorials individually outside of class hours. The academic staff recommended one tutorial per week to be submitted through the virtual campus for correction. Some practical topics are explained only in these tutorials, so it was recommended that they be completed and submitted within the allotted time. Furthermore, they were indispensable for the correct fulfilment of the group project that students are required to complete at the end of the course.

Table 4 shows the three voluntary activities with a summary of all their objectives, scope, methodology, outcomes and feedback.

3. Results and discussion

The results of this STEM postgraduate innovatory teaching project are shown below:

Table 5 provides a summary of the tests (Activity

Table 4. Summary of voluntary activities

Activity	Objectives	Scope	Methodology	Outcomes	Feedback
Activity 1. Theoretical self-assessment test (EP)	Improve learning of theoretical content and individual responsibility	Fosters making of parts, understanding of norms and execution of project	9 self-assessment tests via Atenea on the different topics. Voluntary and individual. Completion according to the schedule in Table 1	Tests completed via Atenea virtual classroom	Automatic correction. Students should ask teachers for the correct answers
Actividad 2. Voluntary exercises	Complete exercises on spatial geometry	Raises qualification of the DAO3	Individual completion of extra exercises.	Sent as assignment through the Atenea virtual classroom	Correction to be done one week after submission. Students are informed individually in class about right and wrong results of the exercises
Activity 3. Example-based learning (Tutorials)	Improvement of making of Solidworks parts	Fosters the realisation of the project and understanding of related topics not addressed in class	12 Tutorials for example-based learning, according to the schedule in Table 1	Drawn up and sent as an assignment via the Ateneas virtual classroom	Correction to be done one week after submission. Exercises approved when teachers ensure that last step in tutorial has been reached

Table 5. Percentages of tests completed by students who passed the subject and those who acquired the autonomous learning competence in groups M32 and M61

M32 (31 Students)				**M61 (29 Students)**			
Tests completed	**% of tests completed (Students)**	**% of students who passed (Students)**	**% of students who passed autonomous learning competence (Students)**	**Tests completed**	**% of tests completed (Students)**	**% of students who passed (Students)**	**% of students who passed autonomous learning competence (Students)**
0 to 3	16% (5)	20% (1)	60% (3)	**0 to 3**	27% (8)	25% (2)	62% (5)
4 to 6	19% (6)	100% (6)	100% (6)	**4 to 6**	17% (5)	80% (4)	100% (5)
7 to 9	65% (20)	80% (16)	95% (19)	**7 to 9**	56% (16)	93% (15)	93% (15)

1) completed by the two groups, together with the percentage of students who passed the subject and the autonomous learning competence. One may observe in this table that 65% of students did the greatest number of tests (7–9), which implies a significant eagerness to learn. One may also observe that for those who did between 4 and 6 tests, the percentage of students who qualified for both the subject and the competence is very high.

Analysis of the results from this activity in the two groups (M32 and M61) shows that 4 students from group M32 and 1 from group M61 who completed between 7 and 9 tests did not pass in the subject (less than 10%), and only two students (one from each group) failed to acquire the autonomous learning competence.

Table 6 presents a summary of the percentage of submissions of Activity 2, as well as the students belonging to the two groups who passed. One may observe that 35% of students (11 students) from group M32 and 34% (10 students) from group M61 completed the experience, and they all passed the DAO3 mid-term exam as well as the subject itself. However, in group M32 only 22% of those who failed to deliver the voluntary exercises passed the DAO3 mid-term exam, a percentage that was even smaller (17%) in group M61. The percentage of students from both groups who did not do the voluntary exercises but passed the subject is only 38%, which corroborates the benefits of the interest shown by students in participating in these voluntary activities even though they do not count towards the final mark.

With the exception of three students (5%, 1 from group M32 and 2 from group el M61), all the others who completed this activity qualified for the autonomous learning competence.

Table 7 provides a summary of Activity 3; here

Table 6. Percentage of voluntary exercises submitted

Group (Students)	**% of submission of voluntary exercises (Students)**	**% of DAO3 passes (Students)**	**% of passes in the subject (Students)**	**% of students who submitted voluntary exercises and passed autonomous learning (Students)**	**% of DAO3 passes who did not submit voluntary exercises (Students)**	**% of passes in subject who did not do voluntary exercises (Students)**
M32 (31)	35% (11)	100% (11)	100% (11)	32% (10)	22% (7)	38% (12)
M61 (29)	34% (10)	100% (10)	100% (10)	27% (8)	17% (5)	38% (11)

Table 7. Percentages of tutorials completed by students in groups M32 and M61 who passed the subject and the autonomous learning competence

M32 (31 Students)				**M61 (29 Students)**			
Tutorials completed	**% of tutorials completed (Students)**	**% of students who passed (Students)**	**% of students who passed autonomous learning competence (Students)**	**Tutorials completed**	**% of tutorials completed (Students)**	**% of students who passed (Students)**	**% of students who passed autonomous learning competence (Students)**
0 to 3	48% (15)	80% (12)	80% (12)	0 to 3	45% (13)	53% (7)	76% (10)
4 to 6	29% (9)	55% (5)	88% (8)	4 to 6	28% (8)	75% (6)	87% (7)
7 to 9	16% (5)	80% (4)	100% (5)	7 to 9	24% (7)	100% (7)	100% (7)
10 to 12	7% (2)	100% (2)	100% (2)	10 to 12	3% (1)	100% (1)	100% (1)

one may see that the percentage of students who completed the greatest number of tutorials (10–12) is very low. This figure is less than 10%, but it increases to more than 50% when the students who completed more than 4 tutorials are taken into account. One may also see that approximately 90% of students from both groups who completed between 4 and 6 tutorials qualified for the autonomous learning competence. It should be pointed out that this activity takes place at the end of the course, when students have a much heavier workload than in other subjects, which probably accounts for why participation is lower.

Table 8 (a and b) shows the summary of the three voluntary formative learning activities, the final autonomous learning results and those for the subject for each student.

Most noteworthy are the students who achieved a mark of over 1.5 in the self-assessment tests (maximum mark 3), those who submitted the voluntary exercises and those who submitted more than 50% of the tutorials, which we assume required a great deal of effort and dedication.

One may observe that only 3 students from group M32 (students 10, 25 and 31) and 2 from group M61 (9 and 17) fulfilled these conditions, all of whom passed the subject with a mark higher than 6 and an autonomous learning result higher than 7.

Nevertheless, 100% of the students who submitted more than 50% of the tutorials also submitted the exercises for the mid-term DAO3 and achieved a score of higher than 1 in the self-assessment test. They passed the subject with a mark equal to or higher than 6 and obtained a score of higher than 7.4 for the autonomous learning competence. So, although these conditions are not indispensable, they are sufficient to achieve a pass mark in both the autonomous learning competence and the subject.

Finally, engagement in the final group project brings together all the topics (theory and problems) and serves to demonstrate whether the students have indeed learned the different topics in the subject. The project accounts for 65% of the total mark for autonomous learning.

A simple dispersion analysis of the marks obtained in the final project and those of the autonomous learning competence of every student is conducted in order to explain that a significant number of students have completed the final project satisfactorily and have obtained a high mark in the autonomous learning competence. Fig. 1.

These simple dispersion graphs employ cartesian coordinates to show the values of two variables for a data set, and are useful for describing the joint behaviour of two variables in which each case is represented as a point on the plane defined by the variables X and Y.

The dispersion analysis shows that a significant

Table 8 (a and b). Summary of the three activities, the autonomous learning mark and the final overall mark in groups M32 and M61, showing the students with the best performance in the three activities

(a)

Group M32	Test mark (out of 3)	Exercises	Tutorials	Autonomous Learning Mark	Final Mark (out of 10)
Student 1	1.3	x	3	4.6	5.2
Student 2	0.5		3	7.3	5.8
Student 3	0.7		5	6.8	3.8
Student 4	1.2	x	10	7.6	6.9
Student 5	0.1		0	0	0.4
Student 6	0.2		0	0.6	0.6
Student 7	0.3	x	1	7.8	6.2
Student 8	2.2	x	3	8.1	7.6
Student 9	0.5		3	7	5.4
Student 10	1.6	x	6	7.9	6.1
Student 11	0.8		3	7.2	6
Student 12	1.2		5	7.2	3.4
Student 13	1.6		4	7.5	5.6
Student 14	0.9	x	0	6.9	5.1
Student 15	1.4		2	7.4	5.1
Student 16	1.3		7	5.1	4.3
Student 17	1.1	x	9	7.8	7.4
Student 18	2.0		0	7.2	5.5
Student 19	1.1		2	7,6	5
Student 20	1.5		1	6.9	5.5
Student 21	1.4	x	8	8	6.5
Student 22	0.2		6	6.5	4.4
Student 23	0.9		3	7.3	6.3
Student 24	1.4		6	7	6.6
Student 25	1.5	x	7	7.4	6.2
Student 26	0.7	x	5	8	6.1
Student 27	0.1		0	7	4
Student 28	1.7		11	8.1	7.2
Student 29	0.4		6	5.4	4.1
Student 30	0.9		4	5.5	5.5
Student 31	1.6	x	9	7.1	6.6

(b)

Group M61	Test mark (out of 3)	Exercises	Tutorials	Autonomous Learning Mark	Final Mark (out of 10)
Student 1	1.1	x	3	8.5	7.9
Student 2	1.2		2	7.4	4.7
Student 3	0.9	x	7	7	5.2
Student 4	0.4		4	0	0,4
Student 5	1.4		4	6.6	5,4
Student 6	0.8		8	7.7	6.4
Student 7	0.0		0	6.6	3.8
Student 8	0.3		6	8.2	7.2
Student 9	1.6	x	7	7.4	7.9
Student 10	1.1		2	8.4	6
Student 11	0.9		8	7.3	5.3
Student 12	0.8	x	1	7.2	5.6
Student 13	1.3	x	9	7.2	6.6
Student 14	1.1		10	6.8	5.9
Student 15	0.4		5	6.1	4.5
Student 16	0.7	x	1	4.6	5.2
Student 17	2.1	x	9	7.2	7.6
Student 18	1.0		4	7.2	5.6
Student 19	0.3		0	6	2.5
Student 20	1.1	x	0	5.7	5.2
Student 21	0.5		0	6.1	4.5
Student 22	0.4		4	6.9	5.7
Student 23	1.2		9	7	6.8
Student 24	1.4		8	6.3	5.3
Student 25	0.3		3	6	4.3
Student 26	0.5		2	7.1	5.9
Student 27	0.2	x	2	4.7	5
Student 28	0.0		0	0.7	2.2
Student 29	1.5	x	4	8.9	6.8

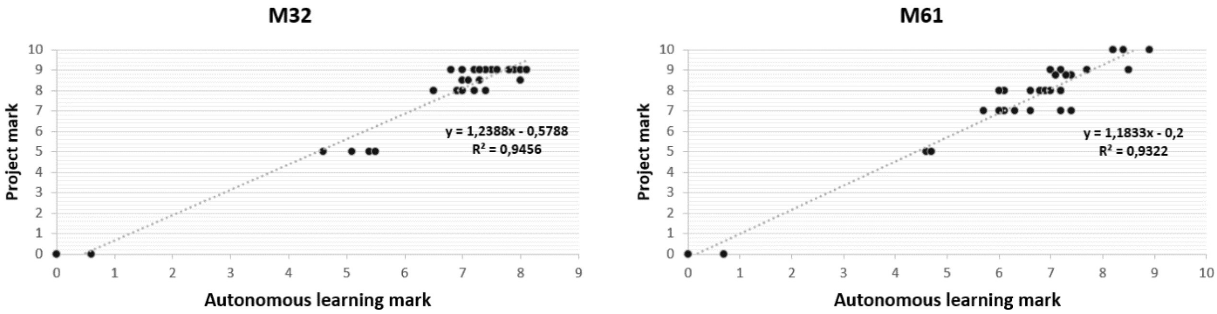

Fig. 1. Dispersion analysis and the coefficient of determination between the test results and the autonomous learning competence results. Groups M32 and M61.

number of students who obtained a high mark for autonomous learning also performed well in the final project, as may be seen in Fig. 1. One may also observe that a functional or direct linear relation exists in both graphs.

The coefficient of determination measures the representivity that the regression line has with reality. Its value is 0.94 for group M32 and 0.93 for group M61, both of which are very close to 1; that is to say, 93% and 94% of the variability of the variable (y) is explained by the adjusted regression model.

3.1 Student satisfaction survey

In order to determine students' opinions, on conclusion of teaching activity and the innovation experience, an anonymous on-line survey using Google Drive® forms was conducted on the groups to whom the course was imparted and who participated in the experience.

The survey of type SEEQ (Students' Evaluation of Educational Quality) [25] is a highly effective instrument for teaching assessment. It revolves around those aspects regarded as being most closely related to the level of acquisition and the assessment of the autonomous learning competence, such as interest in the subject, the understanding of its content and the methods and means of approaching the assessment, among others. There are 5 possible responses: Agree very much, Agree, Neutral, Disagree and Disagree very much.

The purpose of the survey is to verify improvements in the teaching-learning process and the assessment strategies employed for the acquisition of the autonomous learning generic competence.

The results obtained from the survey are process by the IBM SPSS v19 Solutions for Education® statistical programme for the quantitative analysis and the statistical descriptive frequencies of the different variables. Contingency tables are drawn up to analyze crossing of variables, degree of significance and Chi-Square in order to verify correlations between the variables analyzed, where a degree of significance of less than 0.5 implies rejection of the null hypothesis and that the correlations are not random.

The data gathered will serve to improve the strategy implemented in the innovation project (formative assessment) and to verify the quality of the process under assessment (summative assessment), as proposed in [26, 27].

45 students from the groups M32 and M61 responded to the survey out of a total of 61 who were enrolled, which gives a figure of 73%.

In Table 9 one may see a summary of the aspects regarded as those most closely related to the innovation project, together with the list of questions, the weighted averages (out of 5) and the standard deviation.

Knowledge of the students' opinions about the exams and assessment is important for determining the fairness of the methods for evaluating the autonomous learning competence.

Table 9. SEEQ survey questions, weighted averages and standard deviation

Related aspects	SEEQ Survey	Weighted average (out of 5)	Standard deviation
Interest and understanding	My interest in the subject has increased as a result of this course.	3.64	0.88
	I have learned and understood the contents of this course.	3.64	0.71
Exams	The assessment methods for this subject are appropriate and fair.	3.26	1.25
	The exam contents and other work assessed match both the contents of the course and the emphasis placed by teachers on each topic.	3.71	0.81
	I think the teachers have assessed my work fairly.	3.84	0.7
	The approach to course assessment has helped me to learn the academic content better.	3.48	0.75

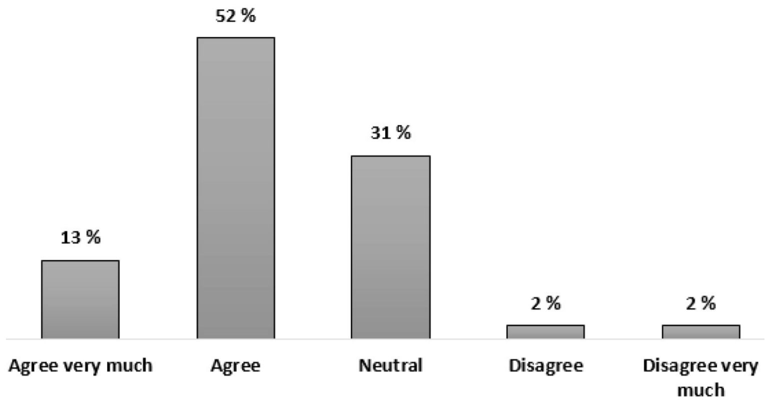

Fig. 2. Question: The exam contents and other work assessed match both the contents of the course and the emphasis placed by teachers on each topic.

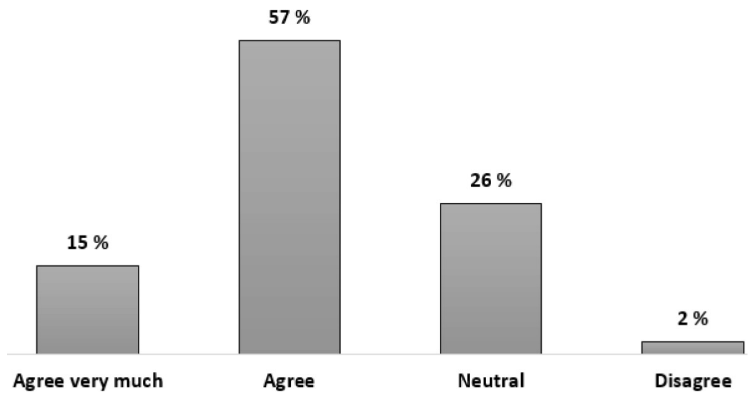

Fig. 3. Question: I think the teachers have assessed my work fairly.

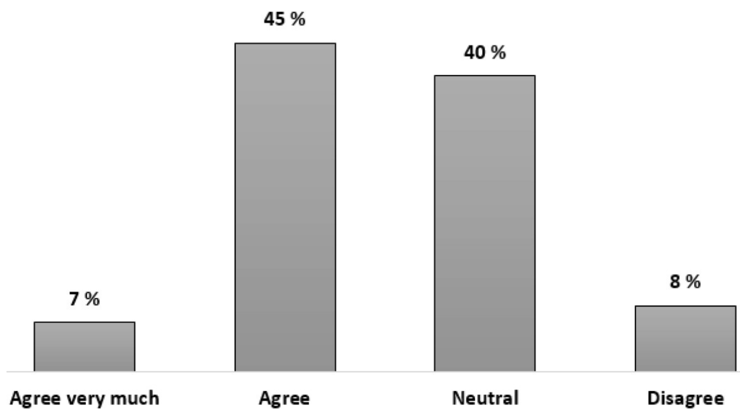

Fig. 4. Question: The approach to course assessment has helped me to learn the academic content better.

When asked whether they thought the methods of evaluation were fair, equitable and appropriate, 50% of students agreed or agreed very much that they were, while 17% stated that they disagreed or disagreed very much.

When asked whether they thought the contents of the exams corresponded with the course contents, 52% of students replied that they agreed and 13% that they agreed very much. Only 4% expressed disagreement or strong disagreement (Fig. 2). Fig. 3 shows the results about the question referring to the fairness of teacher evaluation of the exams; 73% of the respondents said they either agreed or agreed very much that this was fair.

Finally, in answer to the question of whether the approach adopted in the course assessment helped to improve learning of the contents, 52% of students stated that they agreed or agreed very much that it did (Fig. 4).

The results of the survey show that the two aspects most highly rated by the students concern the contents of the exams; they believe that they corresponded with the contents of the course. The other most noteworthy aspect is that the students are of the opinion that the teachers made a fair assessment of their work. These two factors are very positive for the approach taken in the teaching-learning process.

No significant correlations were found in the analysis of the correlation between the different variables, due mainly to the low number of the sample (45 students).

3.2 Reflections on the teaching innovation project

Among other factors, the application of this experience arises from teacher dissatisfaction with the fact that for several years students lacked sufficient motivation in learning the topics on the GE syllabus, and that methods and tools could be employed to improve student motivation and learning. In addition, this fact is combined with the lack of time available in the classroom (3 hours per week) for the teaching and learning of all the objectives required for the subject; thus, it was decided that mainly distance learning activities would be planned.

The effort and the time devoted to the design, programming and evaluation of the voluntary involved a considerable increase in the weekly teacher workload (approximately 50% more). Since this concerned an innovatory teaching experience chosen as an innovative project within the STEM postgraduate course, other teachers responsible for imparting the GE subject did not participate. The work involved in the preparation of the material fell upon only one female lecturer and it was not possible to compare the learning results obtained from this initiative with those of other groups engaged in the subject. Likewise, it was not possible to compare the results with previous courses, since this was the first time that this strategy had been applied.

The effort and dedication to this activity are satisfactory, since in general one sees that participation in these voluntary teaching-learning activities was high and has been useful and effective for the acquisition of the autonomous learning competence.

It is important to stress that the inclusion of these three voluntary activities enables any other teacher of the subject to employ them on future occasions, which would undoubtedly improve the methodology of the subject because it would facilitate student learning and motivation.

The realization of this innovation project has also enabled a senior female lecturer to assess another female colleague with less experience, which gives much greater added value to the project in general.

4. Conclusions

The implementation of this educational innovation project has enabled the methodologies, strategies and the resources acquired during the studies in the STEM postgraduate training programme to be applied and extrapolated. It has also facilitated reflection and observation about the teaching practices employed by the academic staff who participated in this postgraduate course.

The acquisition of teaching competencies on which the postgraduate course is based has led to a significant improvement in the teaching-learning process of spatial geometry, with the incorporation of new activities both inside and outside the classroom. The advantages arising from improvements in the visualization of models and the understanding of problem statements and solutions have enabled the time devoted to theoretical explanations to be reduced as well as involving students more closely in their own learning process.

It is established that participation in the set of non-compulsory programmed activities throughout the course has been high, and that it enhances the acquisition of the autonomous learning competence as well as strengthening spatial conception, knowledge of geometrical shapes and the standard theory of the techniques of graphic representation most commonly employed in engineering.

These activities will be implemented again in future postgraduate courses of this type and voluntary exercises (Activity 2) will be included in the DAO1 and DAO2 mid-term examinations. A new and improved student survey will also be drawn up containing more specific questions in order to introduce these improvements into the process.

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