International Journal of Engineering Education Vol. 31, No. 1(B), pp. 343–353, 2015
Printed in Great Britain
0949-149X/91 $3.00+0.00

Assessing Creativity in Engineering Students: A Comparative Between Degrees and Students in First and Last Year*

MARÍA JESÚS GARCÍA-GARCÍA[1], CONCEPCIÓN GONZÁLEZ-GARCÍA[1], LUIS J. FERNÁNDEZ[2], JOSÉ-LUIS CASADO-SÁNCHEZ[2] and LUISA MARTINEZ MUNETA[3]
[1] ETSI Montes, Forestal y del Medio Natural, Universidad Politécnica de Madrid, Ciudad Universitaria s/n. 28040, Madrid, España. E-mail: mariajesus.garcia.garcia@upm.es, concepcion.gonzalez@upm.es
[2] ETSI Minas y Energía, Universidad Politécnica de Madrid, C/. Ríos Rosas, 21 28003 Madrid. E-mail: luis.fdezgda@upm.es, joseluis.casado@upm.es
[3] CITEF, Centro de Investigación en Tecnologías Ferroviarias. ETSI Industriales, Universidad Politécnica de Madrid, C/. José Gutiérrez-Abascal, 2 28006 Madrid. E-mail: luisa.mtzmuneta@upm.es

An online open access test (CREAX self-assessment) has been used in this work so that students from degrees in engineering in the Universidad Politécnica of Madrid (UPM) could self-assess their creative competence after several classroom activities. Different groups from the first year course have been statistically compared using data from their assessment. These first year students had different professors in the subject 'Technical Drawing' and belonged to several degrees in the UPM. They were as well compared regarding sex and a group of first year students was also compared to another last year group of the degree so as to observe possible differences in the achievement of this competence. Only one difference was detected concerning sex in one of the degrees. Among degrees, the higher marks obtained by students who had done specific exercises for the development of creativity in class is highlighted. Finally, a significantly high mark was observed in students during their last year of degree with respect to first year students. The tool CREAX has become very useful in the assessment of this competence in the UPM degrees in which it has been implemented.

Keywords: engineering creativity; engineering education; CREAX test; e-tool for self-assessment; technical drawing; generic competence; soft skills

1. Introduction

Within the current climate of the European higher education, assuring and enhancing the quality of teaching and learning is a key issue. The European Parliament stated in 2008 [1] that 'teaching and training systems should reinforce the competences creativity and innovation in order to face efficiently the development of the information society'. The European Parliament has recently promoted with his text [2] the investment in education in competences to enhance the socioeconomic development. In this respect, the Universidad Politécnica of Madrid (UPM)has chosen ten competences and Creativity among them, as one of their core competences.

Moreover, the accountability function of assessment and evaluation processes has acquired more importance and ensuring that professionals have the competences, the instruments and the feedback they need to improve their practice [3, 4] has become now the priority in most of the countries.

In this context, the professors of the educative innovation group "Graphical and Cartographical Expression in Engineering" (GIE74) in the UPM have been working since year 2006–2007 on studies related to the development and assessment of generic competences such as teamwork, problem solving creativity [5–7] or self-learning [8] as well as their relation to the academic performance and motivation of students [9].

Outcome oriented education emphasizes the integrated nature of what students must learn in order to fulfill future demands from jobs and life. Both emphasis on input-output and on the learning process are reflected in the assessment of a student performance, moving from knowledge as the dominant (even the single) reference to include a variety of approaches to assess (portfolio, tutorial work, course work; peer, co and self-assessment, etc.). The current competence based education integrates self-regulated learning, project learning, Project Based Learning (PBL), coaching learning, etc. [10].

The GIE74 working team has carried out some projects on Educative Innovation and several experiences in order to implement in class the development and assessment of the competence creativity. The interest in this competence in engineering investigation occurred halfway through the last century [11]. However, there is not much experience in the assessment of creativity in class at engineering universities and it is considered

* Accepted 15 July 2014.

interesting to find a methodology to assess this competence in the different aspects stated before (course work, peer to peer, self-assessment) and that this can be applied to large groups.

Some authors have been working on this field of higher education [12, 13] and specifically on engineering [14–20] although more investigation is still required.

The aims to be achieved by the group with this study have been: a personal assessment for each student and being able to give them a reference of the level of development of their creativity; comparing the results obtained by students from several degrees; comparing within a degree students when they start university (first year students) and when they take their place in society (last year students); also, determining if there were any differences regarding sex.

2. Teaching-learning methodology

The experience is contemplated, on the one hand, for freshmen students of the subject *Technical Drawing* in several engineering degrees of the UPM: Forest Engineering (FE), Industrial Engineering (IE), Technical Forest Engineering (TFE) and Mining Engineering (ME). The subject Engineering Drawing is taught with training in creativity in FE and IE degrees. However, TFE and ME students were taught this subject using a traditional approach.

On the other hand, this study was as well contemplated for the last year students of the ME degree, which had in common a subject to develop soft skills (communication, teamwork, time management and so on).

In order to design learning activities it was considered that the study of creativity in psychology has focused traditionally on divergent thinking abilities [21, 22]. However, we could say that the theoretical constructs to be assessed, which are based on the specific literature about creativity in engineering, are: divergent thinking, through the production of many solutions; convergent thinking, by solving the problems raised; constraint satisfaction, by meeting the parameters established in the instructions and by manipulating the objects; problem finding, through identifying some other uses for the design; and problem solving, that is, creating a new design [15].

Besides, all these activities should combine their potential to develop creativity with the development of typical competences of graphical communication in engineering such as spatial vision and plot engineering drawings.

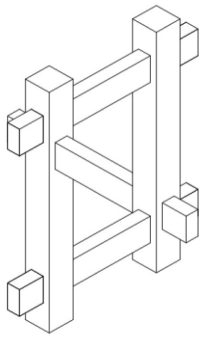
Hence, three types of activities to boost creativity were suggested for the FE group. They comprise three different levels of complexity and would be carried out at different stages of the course, increasing complexity gradually. These types of activities were: resolution of paradoxes, finding alternatives and improving the design of an object. The first two activities should be solved individually while the last in groups. IE students just carried out the teamwork activity. However, TFE students carried out the same activities as FE students, although conventionally presented and without having a previous specific training on creativity.

The Teaching-learning methods used in FE and IE degrees are similar. They included one lecture about introduction of creativity and another one in which are explained and trained creativity techniques such as brainstorming and SCAMPER. In addition, three types of activities were proposed for develop simultaneously creativity and engineering drawing competencies. These types of activities were: resolution of paradoxes (type I), finding alternatives (type II), and improving the design of an object (type II), (Fig. 1). The main difference between FE and IE was the level of development of activity type III, the project of improving the design of an object is longer and more detailed in the case of FE degree. The total number of hours worked by student is 40 hours in both degrees (FE and IE). Moreover, TFE students carried out the same activities as FE students, although conventionally presented and without having a previous specific training on creativity.

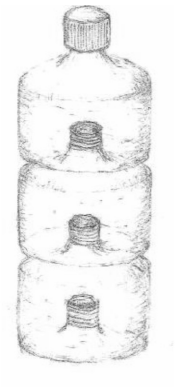
Concerning assessment, we think that it constitutes a fundamental aspect in teaching and learning processes. The general assessment method and the competences assessment in particular, cannot be considered just as an appendix of teaching-learning process but as an integrated and planned element from its origin [23] and so it requires a series of features.

In our opinion, conceiving learning as something active, individualized and based on the cognitive development should imply having an assessment method which started from the active performance of students and which allowed them to apply their knowledge in a creative manner in order to solve real problems.

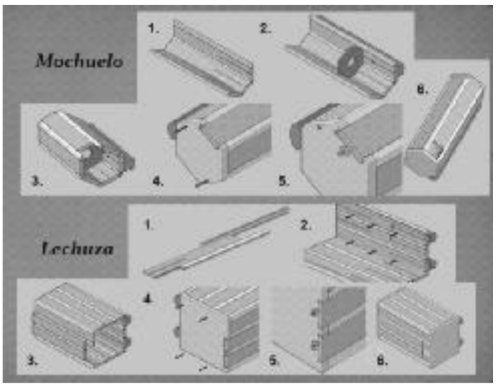
This assessment approach entails an effective use of the knowledge acquired by students in a wide variety of tasks which are significant to the development of competences and which allow them to rehearse for the complex reality of social and professional life [24]. Three complementary assessment approaches were presented in this paper: (a) Tools centred on products, on simulation contexts. (b) Tools focused on the development of activities so as to acquire/boost/promote competences. The resources, which enable continuous and formative



Perspective model for
type I activities



"Fractionated bottle"
sketch
type III in IE



Nestbox by unique element for two species
model in CAD
type III in FE

Fig. 1. Examples of activities type I and type III.

assessment, are crucial here. (c) Tools based on people, their traits and their abilities. Psychometric tests prove to be very useful to evaluate them.

The first two approaches were used to assess FE and IE students through the learning activities suggested along the subject, yet the process observation and the feedback required by the second approach are very difficult to obtain from large groups (this is the case of IE students). However, in order to assess all students it was necessary to select a tool which could be applied regardless of the subject; thus, psychometric tests were used.

Although unconventional in the field of higher education, this sort of tools may contribute to a boosting assessment from the point of view of the individual's features and to cause an important process of reflection for assessment conceived as a self-regulation process [25].

In this case, we used the CREAX test: Creativity Self-Assessment, which was provided by the company CREAX NV as an online tool and with an open access (http://www.testmycreativity.com/).

The test consists of 40 items; it requires no more than 10 minutes, providing an overall personal score which can be compared with a reference value representing an overall average score for the group of people in which the student who performs the test is included. The test also evaluates eight factors (*Abstraction*, *Connection*, *Perspective*, *Curiosity*, *Audacity*, *Paradox*, *Complexity* and *Persistence*), considered to be constituents of the competence "creativity".

The test was applied during the academic course 2009–2010 to first year students of the subject Technical Drawing. The sample size in each degree has been: 29 students in TFE, 72 in IE, 51 in FE; also, during the course 2011–2012, in ME, 41 1st year students and 37 students during their last year. A sample was randomly selected among IE students due to the high number of students registered. In FE, every student of the subject participated in the experience. To TFE and ME students, the test was only applied to one group in the class.

The questions in the test had been previously translated into Spanish and proved in an early project [7]. Students were provided with the questions on paper. The same group of professors submitted students the surveys during class time and explained how to answer them at the beginning, ensuring every student had a computer so as to use the online test application. Once the answers were obtained, they were codified and previously trained staff homogenized the data.

3. Results and discussion

This section covers the main results obtained and the advantages of the approach used in order to promote professional competences, specifically creativity.

Descriptive and comparative analyses were first carried out with the purpose of verifying if there were any differences in the values obtained from the test regarding degrees and gender: on the one hand, of the overall value provided by CREAX as the final result of each test; on the other, of the values obtained in each aspect or factor considered as a component of the competence creativity.

The average figures of the overall result and of every factor, all of them obtained regarding degrees, were then compared with the reference average figures provided by test CREAX, taking into consideration that the text measures in graduates the competences 'engineering professional area' and 'one year of experience'

Finally, a comparison between the values

Table 1. Statistics Summary for Global

Degree	Count	Average	Standard deviation	Coef. of variation	Min.	Max.	Stnd. skewness	Stnd. kurtosis
TFE	29	60.85	11.46	18.84%	33.08	79.53	–1.60	0.30
IE	71	56.87	16.10	28.31%	16.16	88.16	–2.78	0.45
ME	41	61.29	7.10	11.58%	46.59	73.89	–0.55	–0.65
FE	51	60.46	12.92	21.37%	21.59	81.62	–3.79	2.76
Total	192	59.36	13.14	22.14%	16.16	88.16	–6.31	4.20

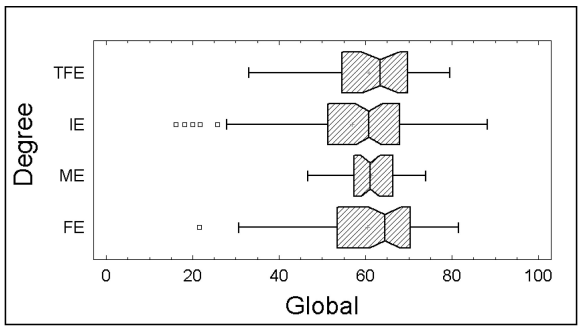


Fig. 2. Box—plot for Global by degrees.

obtained by first year students and those by last year students or finalists within a degree ME was drawn.

3.1 Comparison by degree

A descriptive analysis of the overall value obtained in the test by first year students from the four degrees considered was first performed. Statistics summary is shown in Table 1, where we can see the count of students which answered the test in each degree, as well as the corresponding statistics: average, standard deviation, coefficient of variation, the maximum, the minimum and the skewness and kurtosis standardized coefficients.

The lowest average value corresponds to IE, but this degree also shows the greater dispersion (coef. of var. = 28.31%) as it can be observed in the box-plot (Fig. 2) with some data (5 outliers) 1.5 times under the interquartile range for EI. So, five extreme values are observed for IE, with global lower outcomes than the rest and just one value like this in FE.

Standardized skewness and standardized kurtosis coefficients inform us that distribution values in IE and FE do not allow to assume normality.

In order to compare global values among degrees, Kruskal-Wallis test is used [26]. The comparison between medians (the center line in each box in Fig. 1) is not significant (p-value = 0.58). However, there are differences among variances (p-value = 0.011 of Levene's test [27]) at 5% significance level, due to the lowest dispersion for ME (Table 1).

The descriptive analysis of each factor considered for the competence is summarized in Fig. 3 regarding the degree studied. This figure shows in a chart the mean obtained in each degree and factor.

ME is the degree whose students obtained the highest values in factors such as *abstraction*, *perspective* and *persistence*; while these values were lower in the rest of degrees. IE shows the lowest average values in most of the factors, except for *audacity*, slightly higher than ME; the *complexity* and *perspective* average values are similar to the FE ones and the *connection* average value is similar to the average value of this factor in ME (Fig. 3). The factors in which all the degrees present average

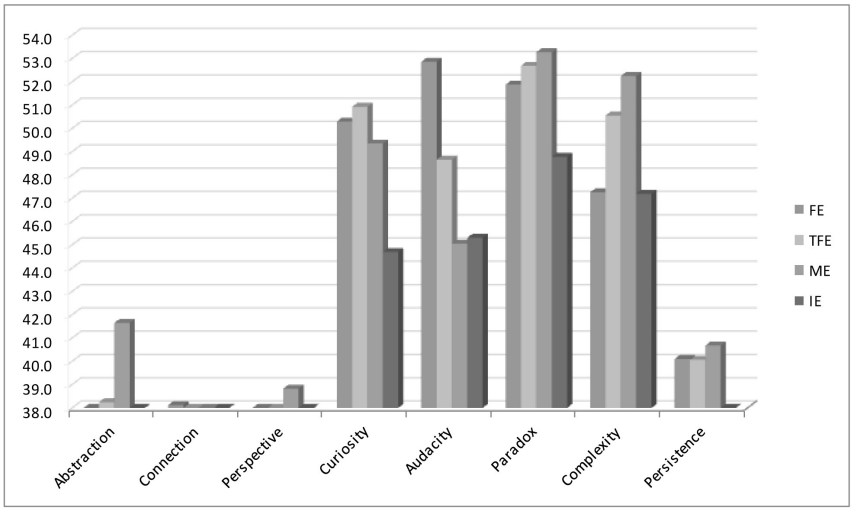


Fig. 3. Average values obtained in the factors regarding degrees.

Table 2. p-values of comparison tests of overall test value and each factor overall values concerning degree and sex

	p-values of tests ANOVA or Kruskal-Wallis								
	Global	**Abstraction**	**Connection**	**Perspective**	**Curiosity**	**Audacity**	**Paradox**	**Complexity**	**Persistence**
Degree	0.583	0.003**	0.084*	0.142	0.218	0.094*	0.639	0.163	0.383
Sex	0.391	0.716	0.817	0.261	0.094*	0.078*	0.530	0.905	0.533

* Significance for 0.1 level. ** Significance for 0.01 level.

values between 44.5 and 53 are *curiosity*, *audacity*, *paradox* and *complexity*. FE is highlighted in the former two factors and ME in the latter.

With regard to normality in the values obtained for each factor, only *perspective* and *audacity* (Kolmogorov-Smirnov goodness-of-fit test [28], $0.05 <$ p-value < 0.1) could be considered as normal. The outcomes of comparing the overall value of the test and of each factor by degrees or sex are collected in Table 2, where significance values of ANOVA test [29] (when it can admit normality and identical variances) and Kruskal-Wallis tests can be observed.

For *abstraction*, there are significant differences among medians by degrees (at 99% confidence level); Duncan's multiple range test [30] shows dissimilarities at 95% level between the pairs IE-ME and ME-FE (Fig. 3). Significant differences among degrees at 90 % confidence level are found for *connection* and *audacity*, that is, differences among groups are lower than in *abstraction*. For overall value of CREAX and of the rest of the factors no significant differences neither among groups nor between sexes have been found. For *connection* and *audacity*, the multiple range test does not detect significant differences between pairs of degrees (Fig. 4).

For *audacity*, there is significance at 0.1 for Fisher's Least Significant Difference (LSD) range test [31] is the only test appreciating differences between FE–IE and ME–FE at 95% confidence level (Fig. 3).

Summarizing these results, statistical hypothesis tests do not detect significant differences among students from the different degrees for the global values provided by the CREAX. ME students show the lowest values in *connection* and *audacity*, although they present the highest values for *abstraction*. Concerning *audacity*, the median is notably deviated towards a higher value for FE students, which had received a specific training in creativity. These differences are very little for *connection*, though slightly higher than in FE and TFE.

Within the frame of higher education, many authors have found significant differences after the implementation of creativity boosting methodologies in class, both in social sciences environments [32] and engineering environments [14], or the two of them together [15, 16]. However, our outcomes are not clear concerning the overall value of creativity.

FE and TFE students have carried out the same kind of activities with the only difference that in FE students received training in creativity specific techniques and were assessed on this competence, although they only stood out in *audacity* factor. This may be due to the comfort felt by FE students in the environment created in class, although they were under additional pressure since they were assessed as well on this competence.

Some authors state that within the frame of university education it is necessary to assess creativity in students but further research is needed in order to assess additional methodologies meeting this requirement. Low risk assessment methodologies should be implemented at the same time as part of an environment suitable for creativity [12], since students confirm on the whole an improvement in motivation and admit that the creative projects suggested enhance their performance in the engineering design and help developing some compe-

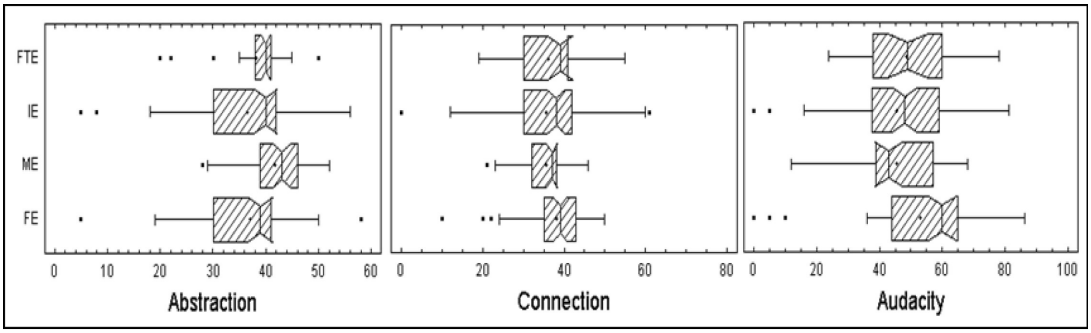


Fig. 4. Comparative of *Abstraction*, *Connection* and *Audacity* by degrees.

tences which are closer to social, industrial and commercial climates [19, 20]. Nevertheless, the atmosphere created within the classroom and individual attention to the development of creativity seems to have a deeper influence than many other factors implied [12]. In this case, IE students did not obtain good results despite the fact of carrying out at least one creativity development oriented work in group. This subject is taught to very large groups of students and so it is complicated to pay individual attention to them.

Otherwise, ME and TFE students have been chosen due to the fact that the demand is higher than the number of vacancies in these degrees. Therefore, these students show distinguishing characteristics which may influence results. Actually, there are some authors who support the idea that personal traits such as *curiosity* or *thoroughness* have a stronger influence over creativity than the cognitive components related to intelligence [33, 34].

According to Sternberg [quoted in 35], creativity is composed of two aspects: the cognitive and the psychometric. Despite efforts on assessing creativity in the teaching of engineering are currently focused on product assessment methods [15, 16, 35], the traditional psychometric tool may prove really useful, particularly if a research in specific professional areas is conducted.

In general, most authors [15, 16, 19, 20, 36] agree on the positive relationship between creativity and learning activities suggested following Project Based Learning (PLB) and which are related to the design area. Thus, creativity is recommended to increase efforts in order to implement the development of this competence in subjects such as Design in any field of engineering, graphical expression, etc. On the other hand, the importance of assessment and its impact on students attitude and motivation [12, 19, 20] proves to be a reason enough to go into detail about a research for assessment approaches which are useful when learning an engineering and which could be applied to large groups. In this sense, the outcomes in this study support the use of similar tools to the implemented test CREAX, as it can be used for large groups and has the additional advantage that it provides students with a reference in their competence level. Students have considered this as a positive feedback during this experience.

3.2 Analysis regarding gender

A comparative analysis by gender has been carried out both to the global value provided by CREAX test and to each of the factors with the total sample (192 students). Table 2 shows the significance values (p-values) obtained with ANOVA and Kruskal-Wallis tests for the specific case of a factor (gender) with two levels. Small differences ($0.05 < p < 0.1$) between sexes are only observed for *audacity* and *curiosity*. Those differences were already observed in a previous study [7] for FE students.

In order to check the homogeneity of the sample regarding degree and gender, a qualitative analysis has been performed with the result of a contingency table. So a Chi-Square test [37] was made in order to determine whether is rejectable or not the idea that distributions of the overall scores of CREAX by degree and sex are independent. Since the p-value = 0.762 resulted greater than 0.05 we cannot reject the hypothesis that sex and degree are independent at a 95% confidence level.

For each degree, a comparative analysis by gender has been also carried out, both to the global value provided by CREAX test and to each of the factors. The descriptive analysis of the overall test score classified by degree and gender provides the outcomes shown in Table 3.

Men students outnumber women in all the degrees considered. The highest dispersion values are observed for IE-Man and FE-Woman, while FE-Man and ME-Woman present the highest average values of the overall test score. The last column in Table 3 shows the percentages of men and women regarding the total amount of students of the first year sample for each degree.

After verifying with skewness and kurtosis standardized coefficients, whether variables in each degree have normal distribution, tests of two mean comparison (t-test [38]) or distributions (Kolmogorov-Smirnov non-parametric test to compare two

Table 3. Statistical summary of the overall test score by degree and sex

Degree—Sex	Sample size	Mean	Median	Std. Dev.	% M-W
IE—MAN	48	58.07	61.21	15.63	68
IE—WOMAN	23	56.13	57.94	15.35	32
TFE—MAN	22	60.57	61.77	11.65	76
TFE—WOMAN	7	61.72	68.94	11.69	24
FE—MAN	33	63.59	66.16	10.21	65
FE—WOMAN	18	54.73	55.96	15.53	35
ME—MAN	29	60.64	60.38	6.76	57
ME—WOMAN	12	62.86	65.67	7.95	24

Table 4. Significance values (p) of *t-test* or *Kolmogorov-Smirnov test* comparing gender for each degree

Degree	Global	Abstrac.	Connection	Perspec.	Curiosity	Audacity	Paradox	Complex.	Persist.
IE	0.48	0.814	0.147	0.275	0.299	0.591	0.267	0.814	0.717
TFE	0.555	0.252	0.379	0.555	0.252	0.555	0.223	0.580	0.680
FE	0.018*	0.109	0.236	0.006**	0.006**	0.012*	0.204	0.642	0.162
ME	0.37	0.897	0.103	0.541	0.407	0.532	0.566	0.847	0.218

* Significant at the 95% confidence level. ** Significant at the 99% confidence level.

samples) have been performed. Table 4 shows the p-values resulting from these tests of comparison in each degree, of the Global or overall scores values of CREAX and of each factor regarding gender.

Concerning the overall value of the test, significant differences are only observed at 0.05 level (t-test for equal variances with p-value = 0.04) in FE. With regard to factors, FE is as well the degree which shows significant differences at 99% (Table 4) in *perspective* (Kolmogorov-Smirnov test) and *curiosity* (t-test), and in *audacity* (t-test) at 95%. In Table 3 we can see a higher mean and a median values for men than for women in this degree.

Few authors have detected differences in creativity regarding gender [15] and in our study, they are only observed in one degree. These differences are due to certain factors which may be strongly related to personality traits. That is the reason why further research is suggested.

3.3 Comparison of reference values with average values for each degree

Once the on-line questionnaire form has been completed, CREAX test website provides with an average result (Fig. 5) of overall score values and of each factor's. These values were obtained for each person individually.

Besides, with these values and so as to establish a comparison, it provides also with the reference values previously obtained from a reference group of professionals (from the "engineering professional area" and having "1 year of experience") where the student answering the test is included. This website does not allow selecting whether students are graduates or not, since it is aimed at professional practice.

In order to verify if the mean (or median) of values of first course students in each degree can be considered the same that reference values provided by CREAX web-site, a statistical analysis has been performed using hypothesis tests (t-test or non parametric test according to whether or not normal distribution). Table 5 shows the average reference values of the Belgian test and the average values obtained for each degree, of the overall scores and for each factor.

No differences are observed for TFE in any case. IE shows the most deviated distribution values from normality and it is the degree with more factors (four of the eight *abstraction*, *audacity*, *complexity* and *curiosity*), as well as global values with averages which are significantly different than reference values In FE degree there are significant differences with reference values in *Abstraction* and *Complex-*

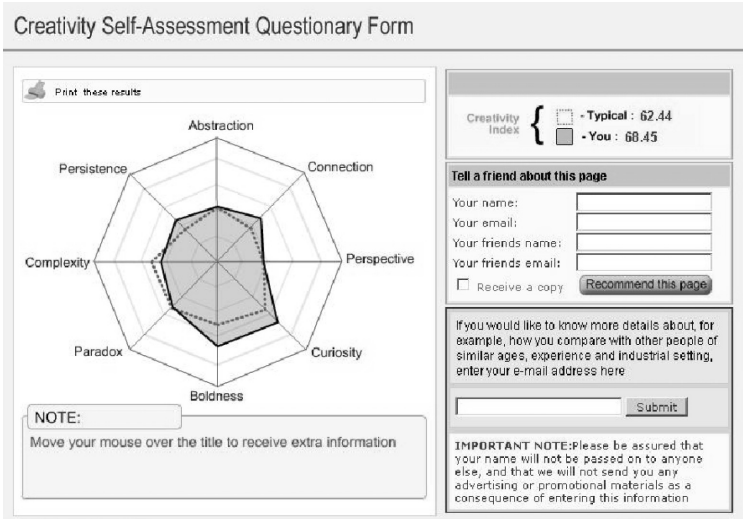


Fig. 5. Results provided by CREAX test website after completing the on-line questionnaire form ("Typical" indicates CREAX reference value and "You" is used to refer to the "global test value").

Table 5. Average reference values for Belgian CREAX test and for each degree and students group

Creat.	Global	Abstrac.	Connec.	Perspec.	Curios.	Audac.	Paradox	Complex.	Persist.
Ref. Mean 1st	62.44	40.75	38.25	37.75	54.75	51.00	51.50	53.50	36.25
TFE	60.85	38.24	36.10	37.38	50.93	48.66	52.69	50.55	40.07
IE	56.87*	36.46*	35.69	34.93	44.69*	45.31*	48.78	47.19*	35.54
FE	60.46	37.06*	38.12	35.69	50.29	52.86	51.88	47.25*	40.10
ME	61.29	41.80	35.56*	38.93	49.61*	45.46*	53.56	52.63	40.76*

* Significant differences with the reference value, p-value < 0.05).

ity. Significant differences with reference values can be observed in ME degree for *audacity*, *connection, curiosity* and *persistence*. Students' means which are significantly different than reference values (* in Table 5) are slightly lower in all the cases except for *persistence* in ME, where the mean is higher than the average value provided by CREAX for this factor.

The fact that most of the significant values obtained by the groups of students are lower than the corresponding reference value can be justified on the grounds that first year students are being compared to one-year experience engineering professionals; in this sense, our students considered that comparing their level with professionals is really motivating.

However, reviewing this data is considered interesting for the teaching practice, since traditional learning approaches adopted by ME students show lower values for factors such as *audacity*, *connection* and *curiosity*, although higher for *persistence*. Regarding FE, where more flexible methodologies were followed and the development of creativity during the subject was implemented, this degree presents lower results in *abstraction* and *complexity*. Therefore, it would be advisable that professors made an extra effort in designing learning activities and in the planning of subjects, a goal we are not always prepared or motivated enough to achieve [13].

3.4 First and last year comparison in mining engineering (ME)

A group of ME last year students also completed the questionnaire, thus we could verify if there were any differences among the means (or central values such as medians) obtained during the first or last year, as well as last year results compared with reference values.

Comparative analysis for values of overall scores

For values of overall scores (Global variable) from students in their first year and from students who are about to finish their degree, a descriptive analysis about normality is performed (asymmetry and kurtosis standard coefficients both within the normal range $\pm$ 2). Equality of variances of the two groups is accepted (p-value > 0.05 of F-test [39]). The t-test to compare the means of the two groups of students (p-value = 0.007) rejects the equality of means. It should be note the high average value (66.20) of last years' students with regard to CREAX reference value (62.47) and the average value of first years' students (61.29).

Comparative analysis of CREAX reference values with the means of final year students

Similarly to the analysis in Table 5, this section includes the results of comparative analysis of CREAX reference values with the means of final year students for each factor (Table 6). In first year students group, significant differences appear in *connection*, *curiosity* and *audacity* (* in Table 6) with mean values lower than CREAX reference value except for the case of *persistence* whose value is above the reference. However, significant differences in last year students appear for scores above the reference value of the test in all the cases, and also above the values of *first year students*.

Comparative analysis between the ME groups regarding factors

A Duncan test was used at 95% in order to compare the values of the two ME groups (first and last year) within the UPM. Significant differences were only appreciated for the factors *audacity* and *curiosity*, with the highest values for last year students.

Gender-based differences were not found for any of the situations, either within the degree or among

Table 6. Reference average values provided by CREAX and obtained by ME first and last year students

Creat. fac.	Global	Abstrac.	Connec.	Perspec.	Curios.	Audac.	Paradox	Complex.	Persist.
Ref. Mean Final stud.	62.47	42.00	38.50	37.00	55.50	52.00	53.00	54.00	35.50
ME Final	66.20*	45.16*	39.11	39.49	54.49	57.54*	57.57*	56.38	44.51*
ME 1st	61.29	41.80	35.56*	38.93	49.61*	45.46*	53.56	52.63	40.76*

* Significant difference with the reference value, p-value < 0.05.

university years, both for global values and for each factor values.

These results seem to show that engineering learning, even using traditional approaches, improves on the whole creativity in students and relates permanently this area of knowledge to the competence, according to some authors opinion [14, 19, 20]. Otherwise, maturity and personal and cognitive development may have a great influence on the enhancement of this competence [12], since many professors believe that this competence is continuously developed throughout live [13].

4. Future issues

The results obtained have allowed us to generate interest on the teaching practice. Which elements can the teaching staff modify in order to improve creativity in our professional practice? How can they be efficiently implemented in class? How do we redesign learning activities so that they become greater creativity boosters? In which subjects within a degree curriculum is implementing the development of creativity more effective and stimulating for students?

Moreover, some of the results obtained encourage expanding the research in order to answer some questions which are more related to the social sphere: Are women less creative that men in engineering area?

5. Conclusions

Taking into account the results achieved, we can conclude that teaching practice can improve creativity in engineering students. The teachers have sense some changes during just one year and with techniques that had been applied to only one subject. There are strengths in traditional teaching, which should be considered for the improvement of university courses. Combining training in class with the design of teaching activities oriented to creativity and the integration of the competence in the assessment method is suggested. However, students attitude is regarded as something very influential; therefore, it is necessary to agree the objectives with them and to create the right climate for the development of the course, both during and after class.

These outcomes are not conclusive with concern to the differences observed by sex, although some significant differences have been found regarding creativity between first and last year students within a degree, and also between them and the average value provided by CREAX test, which includes one year experience engineering professionals. For this reason, engineering programmes in the Universidad Politécnica of Madrid may favour the development of this competence and these subjects into of academic terms constitute a good chance to develop it.

References

1. Commission of the European Communities. Proposal for a Decision of the European Parliament and of the Council concerning the European year of Creativity and Innovation 2009. Brussels, 28.3.2008 COM (2008) 159 final.
2. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Rethinking Education: Investing in skills for better socio-economic outcomes. Strasbourg, 20.11.2012. COM (2012) 669 final.
3. J. Biggs, The reflective institution: assuring and enhancing the quality of teaching and learning, *Higher Education*, **41**, 2001, pp. 221–238.
4. C. A. Palomba and T. W. Banta (eds.), Assessing student competence in accredited disciplines: pioneering approaches to assessment in higher education, *Stylus Publishing, LLC*, Sterling, VA Canada, 2001, pp. 293. ISBN: 1-57922-034-7 (http://f3.tiera.ru/1/genesis/645-649/648000/995188434fbb545e179decd936c34182)
5. M. J. García-García, C. González and R. Argüelles, Methodological changes in technical teaching in order to the European higher education area comparison between countries: Italy and Spain, in *Proc. 2009 World Conference on Educational Sciences*, Nicosia, Cyprus February, 2009, pp. 2701–2706. Published: *Procedia—Social and Behavioral Sciences*, **1**(1), 2009, pp. 2701–2706. Edited by Huseyin Uzunboylu and Nadire Cavus www.sciencedirect.com/science/journal/18770428
6. M. J. García-García, G. Arranz Manso, J. Blanco Cotano, M. Edwards Schachter, W. Hernández Perdomo, L. F. Mazadiego Martínez and R. Piqué, e-Competentis: a tool for evaluation of generic competences, *Revista de Docencia Universitaria*, **8**(1), 2010, pp. 111–120.
7. M. J. Garcia-Garcia, C. Gonzalez-Garcia, G. Dorado and L. J. Fernandez, Development and Assessment of the Competence Creativity Applied to Technical Drawing. International Conference on Educational Sciences and Technology, ICEST 2011. *Proc. of World Academy of Science, Engineering and Technology* **77**, 2011, pp. 997–1001. (http://oa.upm.es/12421/2/INVE_MEM_2011_104743.pdf, accessed June, 30, 2013).
8. M. J. de Teresa, M. J. Garcia-Garcia, G. Dorado, L. J. Fernández, R. Marivela, R. Argüelles, L. F. Mazadiego and A. Tellado, Edugraphica: e-Tool for technical drawing self-Learning and self-Evaluation. *American Society of Agricultural & Biological Engineers (ASABE), Annual International Meeting*, Reno, Nevada, USA. 2009, paper num. 096468, pp. 1–15.
9. J. E. Pérez-Martínez, M. J. García-García, W. Hernández-Perdomo and M. J. Villamide-Díaz, Analysis of the results of the continuous assessment in the adaptation of the Universidad Politécnica de Madrid to the European Higher Education Area, *Proceedings of the Research in Engineering Education Symposium* (*REES* 2009). Cairns, Queensland, Australia, 2009, pp. 1–6.
10. M. Edwards, L. M. Sánchez-Ruiz and C. Sánchez-Díaz, Achieving Competence-Based Curriculum in Engineering Education in Spain, *Proceedings of the IEEE. USA*, **97**(10), October 2009, pp. 1727–1736.
11. E. S. Ferguson, *Engineering and the mind's eye*, Cambridge, MA: MIT Press, 1992, pp. 827–836.
12. D. G. Cole, H. L. Sugioka and L. C. Yamagata-Lynch, Supportive Classroom Environments for Creativity in Higher Education, *The Journal of Creative Behavior*, **33**(4), 1999, pp. 277.
13. J. Paredes, Transformar la enseñanza universitaria con la formación mediante la creatividad. Una Investigación-acción con apoyo de las TIC. *Revista Iberoamericana de Educación Superior*. (*RIES*). núm. 5, vol. II, 2012, pp. 101–

113. http://ries.universia.net/index.php/ries/article/view/58, Accessed 20 July 2013.
14. N. Ishii, Y. Suzuki, H. Fujiyoshi, T. Fujii and M. Kozawa, A framework for designing and improving learning environments fostering creativity, *Psicologia Escolar e Educacional*. vol. **11**, 2007, pp. 59–69. http://www.redalyc.org/articulo.oa?id=282321823006, Accessed 20 July 2013.
15. C. Charyton and J. A. Merrill, Assessing General Creativity and Creative Engineering Design in First Year Engineering Students, *Journal of Engineering Education*, **98**(2), 2009, pp. 145–156.
16. C. Charyton, R. J. Jagacinski, J. A. Merrill, W. Clifton and S. Dedios, Assessing Creativity Specific to Engineering with the Revised Creative Engineering Design Assessment, *Journal of Engineering Education*, **100**(4), 2011, pp. 778–799.
17. T. Bjorner, L. B. Kofoed and J. R. Bruun-Pedersen, Creativity in Project Work—Students' Perceptions and Barriers, *International Journal of Engineering Education*, **28**(3), 2012 pp. 545–553.
18. B. Blandin, The Competence of an Engineer and how it is Built through an Apprenticeship Program: a Tentative Model, *International Journal of Engineering Education*, **28**(1), 2012, pp. 57–71.
19. J. Han, S. H. Yoo and E. Y. Kwon, The Educational Effects of an Introductory Engineering Design Course based on Creative Projects, *International Journal of Engineering Education*, **28**(4), 2012, pp. 818–823.
20. C. Zhou, A. Kolmos and J. D. Nielsen, A Problem and Project-Based Learning (PBL) Approach to Motivate Group Creativity in Engineering Education, *International Journal of Engineering Education*, **28**(1), 2012, pp. 3–16.
21. E. P. Torrance, *Torrance tests of creative thinking: Norms and technical manual*, Lexington, MA: Personnel Press/Ginn Xerox. 1974 (WorldCat data base: http://www.worldcat.org/title/torrance-tests-of-creative-thinking-norms-technical-manual/oclc/42318016?referer=br&ht=edition)
22. J. P. Guilford, Varieties of divergent production, *Journal of Creative Behavior*, **18**(1), 1984, pp. 1–10. Online ISSN: 2162-6057. DOI: 10.1002/j.2162-6057.1984.tb00984.x
23. S. Rodríguez (coord), *Marco general para el diseño, el seguimiento y la revisión de los planes de estudio y programas*. (AQU Catalunya), 2002, http://www.aqucatalunya.org/uploads/publicacions/arxiu%20pdf/MGPlansEstudis_cat.pdf
24. G. Wiggins, The case for authentic assessment, *Practical Assessment, Research & Evaluation*, **2**(2), 1990.
25. A. B autista García-Vera, E. Cano Garcia, P. Diez Arcos, J. L. Estefanía Lera, J. Gairín Sallán, J. López Martínez, C. Monereo Font, N. Sanmartí Puig and M. A. Santos Guerra, *Nuevas funciones de la evaluación, La evaluación como autorregulación*, Madrid, MEC, 2009.
26. W. Kruskal and W. A. Wallis, Use of ranks in one-criterion variance analysis, *Journal of the American Statistical Association*, **47**(260), 1952, pp. 583–621.
27. H. Levene, In *Contributions to Probability and Statistics: Essays in Honor of Harold Hotelling*, I. Olkin et al. eds., Stanford University Press, 1960, pp. 278–292. (http://docs.scipy.org/doc/scipy-0.13.0/reference/generated/scipy.stats.levene.html, accessed, Janvier 2014).
28. I. M. Chakravarti, R. G. Laha and J. Roy, *Handbook of Methods of Applied Statistics*, Vol. I, John Wiley and Sons, 1967, pp. 392–394. (LC control n°: 66026737) http://lccn.loc.gov/66026737.
29. D. Peña, *Regresión y Diseño de Experimentos*, Alianza Ed. Madrid, 2010.
30. D. B. Duncan, Multiple range and multiple F tests, *Biometrics*, **11**, 1955, pp. 1–42.
31. R. R. Wilcox, *Applying Contemporary Statistical Techniques*, Academic Press, San Diego, CA, 2003.
32. D. Bruton, Learning creativity and design for innovation, *International Journal of Technology and Design Education*, **21**(3), 2011, pp. 321–333. DOI 10.1007/s10798-010-9122-8.
33. M. Batey, A. Furnham and X. Safiullina, Intelligence, general knowledge and personality as predictors of creativity, *Learning and Individual Differences*, **20**, 2010, pp. 532–535.
34. M. J. Sanchez-Ruiz, D. Hernández-Torrano, J. C. Pérez-González, M. Batey and K. V. Petrides, The relationship between trait emotional intelligence and creativity across different subject domains, *Motivation and Emotion*, **35**(4), 2011, pp. 461–473. DOI: 10.1007/S11031-011-9227-8.
35. S. K. Oman, I. Y. Tumer, K. Wood and C. Seepersad, A comparison of creativity and innovation metrics and sample validation through in-class design projects, *Research in Engineering Design*, **24**(1), 2013, pp. 65–92. (http://web.cs.wpi.edu/~dcb/Papers/ICCC13/ICCC-DCB.pdf).
36. H. Demirkan and Y. Afacan, Assessing Creativity in Design Education, *Design Studies*, **33**, 2012, pp. 262–278. Elsevier.
37. W. J. Conover, *Practical Nonparametric Statistics*, (3rd edition). Wiley, 1999.
38. D. Peña, *Fundamentos de Estadística*, Alianza Ed. Madrid, 2001.
39. W. G. Snedecor and G. Cochran, *Statistical Methods*, 8th Edition, Iowa State University Press, 1989.

María Jesús García-García is an Associate Professor of Graphical Expression Research at Universidad Politécnica de Madrid, Spain, in which she received her Ph.D. degree in Agricultural Engineering in 2007. Her current research interests are in forest and environmental management, urban greening, assessment by public participation, geographic information systems and educational innovation in higher education.

Concepción González García is an Associate Professor of Applied Statistics and Operational Research at Universidad Politécnica de Madrid, Spain, in which she received her Ph.D. degree in Forestry Engineering in 1989. Her current research interests are in stochastic modelling for forest and environmental management, urban greening, assessment by public participation and educational innovation in higher education. Currently she is Vice-Director for Quality, Innovation Education and Accreditation in Escuela Técnica Superior de Ingenieros de Montes (UPM).

Luis Jesús Fernández Gutiérrez del Alamo is a Professor of Graphical Expression Research at Universidad Politécnica de Madrid, in which he received his Ph.D. degree in Mining Engineering in 1995. His current research interests are in geographic information systems and educational innovation in higher education. Nowadays he is Assistant Director of the Departament of Explotación de Recursos Minerales y Obras Subterráneas.

José-Luis Casado-Sánchez is a registered Auditor (ROAC, Official Register of Financial Auditors Spain), has a degree in Economics (UNED), a degree in Tourism (U. Rey Juan Carlos), and an EMBA from IESE (Universidad de Navarra). Since 2004, he holds a Part Time position as Associated Professor in Universidad Politécnica de Madrid, in which he acquired his Ph.D. in 2012 with an investigation into mining business valuation. His research work ranges from business valuation to educational management.

Luisa Martínez Muneta received her Mechanical Engineer degree from the Universidad Politécnica de Madrid (UPM) in 1990. She got her PhD Degree in 1997 working on variational geometry. Since 1990 she started to work as Associate Professor at UPM. She usually works in the field of computer graphics, simulation and virtual reality. Since 2006, she coordinates a Teaching Innovation Group supported by UPM. During this time she has been involved in different industrial projects and pilot activities promoted by the European Commission and other Spanish institutions. She has published over 32 papers and has been actively involved in more than 27 educational projects.