

Development and Assessment of the Competence Creativity Applied to Technical Drawing

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Abstract—The results obtained after incorporating the competence “creativity” to the subject Technical Drawing of the first course of the Degree in Forestry, Technical University of Madrid, are presented in this study. At first, learning activities which could serve two functions at the same time -developing students’ creativity and developing other specific competences of the subject- were considered. Besides, changes in the assessment procedure were made and a method which analyzes two aspects of the assessment of the competence creativity was established. On the one hand, the products are evaluated by analyzing the outcomes obtained by students in the essays suggested and by establishing a parameter to assess the creativity expressed in those essays. On the other, an assessment of the student is directly carried out through a psychometric test which has been previously chosen by the team. Moreover, these results can be applied to similar or could be of general application.

Keywords—assessment competence, assessment creativity, creativity, generic competences

I. INTRODUCTION

DEVELOPMENT and assessment of generic competences applied to the new degree subjects is one of the most researched issues by the educative innovation group GIE74 Expresión Gráfica y Cartográfica (‘Graphic Expression and Cartography’) from the Technical University of Madrid. Some works regarding teamwork, problem solution, creativity [1], [2] and autonomous learning [3], as well as their relationship with students’ academic performance and motivation [4] have been carried out recently.

The interest which lies in the development of creativity by our students is fully justified since the European Parliament stated that Europe needs to strengthen its capacity for creativity and innovation in order to effectively face the development of the information society, and also that education and training systems should facilitate the development of these competences at all levels [5]. However, the Technical University of Madrid considered ‘creativity’ as one of the eight key competences to be developed in all the new degrees adapted to the European Higher Education Area (EHEA). Thus, the GIE74 produced several teaching materials

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when these works were carried out and so considered the opportunity of elaborating these texts aimed at promoting the development of creativity by students taking this subject. Nevertheless, no previous works or clear precedents in order to develop this kind of activities and let alone to establish assessment methods for this subject have been found. That is why, the project Development of the competence creativity: implementation to Graphic Expression in Engineering was suggested. It was funded by the UPM (Technical University of Madrid) in 2009 and part of the results obtained are stated in this paper. When designing the new degrees in Forest Engineering and Natural Environment Engineering, the convenience of developing and assessing some generic competences in the subject ‘Graphic Expression in Engineering’, creativity among them, was taken into account. Therefore, in the light of their implementation to the new studies it was necessary to have at our disposal learning activities which developed this competence as well as assessment systems and tools for it.

Hence, the group considered dealing with the following objectives: 1) Developing activities to boost creativity and which could be implemented to subjects in the area of Graphic Expression in Engineering. 2) Implementing some of these learning activities to the subjects in Technical Drawing from the Degrees in Forestry and Forest Engineering. 3) Estimating the impact of these activities on students’ creativity. 4) Designing an assessment method for the competence creativity which could be generically applied to the new degrees. 5) Implementing this method and obtaining the first results: analyzing the previously studied aspects of creativity and then observing the differences found in men and women, as well as establishing the possible correlation between students of this subject and their academic performance.

II. METHODOLOGY

A. Design of learning activities

A working group consisting only of professors of the area of graphic expression in engineering was formed with the aim of trying to find, analyzing and suggesting several kinds of learning activities. First of all, a map of the creative activities of the subject was made: the key points where the new creativity activities to be suggested should be included were identified following the relationship <<specific competences–contents–learning activities>>. We noticed that the activities

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linked to the specific competences ‘spatial view’ and ‘drawing maps in forestry engineering’ appeared to be the most favourable ones for the implementation of several creativity techniques. Besides, these are two essential competences which would be advisable to boost and work on in greater depth in the new studies. Then, a systematic review of a big amount of the existing teaching materials, which have been used for the last fifteen years to teach graphic expression subjects by professors of the group, was carried out. After being analyzed, some typical tasks were identified, selected and classified according to their potential as creative activities. Another group, a multidisciplinary one this time, reviewed various creativity techniques and chose the most appropriate to be applied to the subject. The study of creativity in psychology has focused traditionally on divergent thinking abilities [6], [7]. 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 problem 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 [8]. Finally, three types of activities to boost creativity were suggested. They conveyed three different levels of complexity and would be carried out at different stages of the course, increasing complexity gradually. The first two activities should be solved individually and the last in groups.

Activity type I: resolution of paradoxes. Students in the control group must make the Orthogonal Projections of some models in perspective. For this creative activity, students are provided with some models which are similar to the traditional ones but whose solutions seem to be impossible, such as some of the creations from the artist and draftsman Maurits Cornelis Escher (Fig. 1).

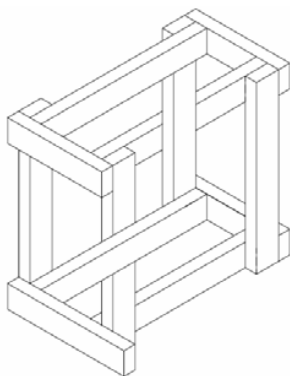


Fig. 1 Perspective Model for type I activities

Activity type II: finding alternatives. In a next stage, students must make a projection in perspective from the dihedral flat projections (the reverse process of the previous

activity). The changes to boost creativity this time consisted of removing some parts of the flat projections, so that their combination could lead to different models depending on the element and the position chosen.

Activity type III: improvement in the design of a ‘forest object’. The control group is suggested to draw a set of engineer maps to define the design of a forest object. In this case, a “nestbox” was proposed. As for the creative activity, the team is said to include ‘any improvement in the design of the “nestbox” and to include as well some drafts of the different alternative designs considered.

The involvement of the learning activities suggested in the assessment of the different constructs abovementioned ranges (Table I).

TABLE I
ASSESSMENT OF CONSTRUCTS: CONTRIBUTION BY ACTIVITY

	Typical-Task		
	I	II	III
Divergent thinking		x	x
Convergent thinking	x	x	x
Constraint satisfaction	x	x	x
Problem finding			x
Problem solving		x	x

Moreover, some kind of training on creativity techniques was considered essential for students since they had never received any in other subjects. Nevertheless, it must be carried out within a very short period of time in class.

In order to develop the three activities, some readings about how to find alternatives [9] were suggested as well as training sessions based on the brainstorming and the SCAMPER techniques [10] and directed at the project ‘improvement in the nestbox’ were carried out.

B. Design of the assessment method

Assessment constitutes a fundamental aspect in teaching and learning processes. The assessment method in general and competences assessment in particular cannot be considered just as an appendix of the teaching-learning process but as an integrated and planned element from its origin [11] and so it requires a series of features. Assessment needs to be: useful, in order to identify and examine positive and negative aspects in the teaching-learning process; planned: scheduled, well-considered and properly prepared and in harmony with the teaching-learning process; feasible: it involves using procedures and tools which are viable and facilitate improvements without making the process of teaching and learning difficult or hindering it; consistent: with the objectives established, the teaching methods used and with the learning results expected; ethical: it implies explicit compromises and a protection of rights; accurate: it must clearly describe the purpose or intention of the assessment along its development and within its context. As far as we are concerned, conceiving learning as something active, individualized and based on the cognitive development should imply having an assessment method which starts from the active performance of students and which allowed them apply their knowledge in a creative way 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 rehearse for the complex reality of social and professional life [12] Competence cannot be handled in all its complexity but can be inferred from performance. This implies considering different ways of performing, what will make it possible to gather enough quality evidence to make a reasonable judgment of somebody's competence [13]. Three complementary approaches of assessment were presented in this work:

a) Tools based on people, their traits and their abilities. Psychometric tests prove to be very useful to evaluate them.

b) Tools focused on the development of activities so as to acquire/boost/promote competences. The resources which enable continuous and formative assessment are crucial here.

c) Tools centered on products, on simulation contexts.

Moreover, the assessment of creativity has been described in some studies as the assessment of the person, the process, the product and the environment [14], [15].

The need for carrying out an assessment of integration was as well considered, that is, an assessment applied both to the specific competences of the subjects and the generic competences developed in it (teamwork and creativity). Therefore, the design was determined to incorporate tools from the three aspects mentioned before, omitting the environment since it is already determined in our case.

On the one hand, the competences teamwork and creativity were partially assessed by using psychometric tests. Although unconventional in the field of higher education, this sort of tools may contribute to a boost 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 [16].

"Self-efficacy for teamwork and teamwork behavior questionnaire items" [17] was used as the tool to assess teamwork and "CREAX Creativity Self-Assessment", which was provided for free and online by the firm [18], to assess creativity.

On the other hand, observation templates were designed in order to assess the processes developed in class when the activity type III to improve the design of a nestbox was being carried out.

At last, the works submitted were assessed according to technical quality criteria, which met the requirements of specific competences, and creativity criteria, taking into account the basic level in engineering design of first-year students.

C. Pilot project: implementation in the subject Technical Drawing of the degrees in Forestry and Forest Engineering

The implementation of the method designed was carried out in the subject Technical Drawing of the degrees Ingeniero Técnico Forestal (Technical Forestry Engineering) and Ingeniero de Montes (Forestry Engineering).

The schedule of the subject in the degree in Forest

Engineering and the assessment system designed were suggested to all the students registered: one hundred and fifty-four students divided into three different classes. Only thirty-three men and eighteen women completed the promoting process of creativity. A total of fifty-nine students sat and forty-four preferred to be assessed through a final examination. Technical Forestry Engineering students acted as a reference group, namely, they were suggested activities based on traditional contents and methodologies and they were not trained in creativity techniques. Only one of the two groups of the degree participated this time: a total of twenty-nine students (seven of them were women). Subjects are similar in both degrees, which are both annual subjects. The study load is slightly heavier in Forestry: an amount of 150 in-class sessions along the academic year compared to the 120 in Forest Engineering. The group of professors who assisted those students was the same in both degrees, although the assessment of projects and the tasks set were carried out by other professors who are not taking part in this work.

III. RESULTS AND DISCUSSION

A. Analysis of the global value of CREAX test

A total of 51 surveys in Forest Engineering (FE) and 29 in Technical Forestry Engineering (TFE) have been considered to be correct. The latter group constitutes the reference group.

A contingency table was obtained and no relationship between the genre and the degree was found after doing a chi-square test.

Then, a descriptive study was carried out in order to estimate the global value of CREAX test for each person regarding the degree studied and in concern with the genre depending on the degree (Table II).

TABLE II
STATISTICS SUMMARY FOR CREAX TEST BY DEGREE AND SEX

Degree	n	Mean	Median	Std.	Std.
				Dev.	error
FE	51	60.46	64.48	12.92	1.81
TFE	29	60.85	63.37	11.46	2.13
FE - Man	33	63.59	66.16	10.21	1.78
FE - Woman	18	54.73	55.96	15.53	3.66
TFE - Man	22	60.57	61.77	11.65	2.48
TFE - Woman	7	61.72	68.94	11.69	4.42

The 95.0% confidence interval for the mean of FE 60.4629 +/- 3.63393 is [56.829; 64.0969] that it contains the reference value 62.43 of CREAX test.

Thus, although some of the students surveyed obtained a slightly lower mean than the reference value (62.43), no significant differences have been found, so these students can be considered to have an average creativity within their group, according to the data provided by the firm CREAX NV. The same occurs for TFE students and naturally there are no differences between degrees.

So students' creativity seems not to be influenced by the activities and promoting training carried out. It would be necessary to widen the study, since it has been proved in other studies [19] that there are some other factors which have a crucial influence on several learning aspects, such as the size of groups and the student-professor ratio.

However, the results obtained in the assessment of the product are encouraging, as judges took a favourable view of most of the nestbox works submitted. Students from the reference group, given the fact that they were not trained or guided towards creativity, submitted works where changes in the models designed were minimal.

For TFE students there were no significant differences regarding sex. Nevertheless, for FE and the factor sex, significant differences were found between CREAX Test global value and sex ($p = 0.04$), at 5% of significance level of a t-test (95.0% confidence interval for means difference: 8.86 ± 8.38 , [1.42973,16.2886]; and for the ratio of variances [0.173658; 0.960399])

Significant differences between sexes, favouring women, have been found in other studies about creativity in engineering [20], [21] in the retest carried out by the students who were trained in creativity, but there were no differences for the students who did not.

The same phenomenon has occurred in our study, with the only change that significant differences have been found in men and not in women.

Researchers suggest some causes in order to explain this situation; however, they consider that deepening in this research is required. No valid causes to justify this difference have neither been found in our case, so we propose as well continuing with the research in this line.

B. Analysis of CREAX test values regarding factors

Abstraction, Curiosity, Paradox and Persistence do not show significant differences between FE and TFE samples. Nevertheless, Connection, Audacity, Perspective and Complexity deserve to be studied separately, since the differences between FE and TFE means were bigger. Audacity was analyzed because it showed the higher increase (4.21 in absolute terms) and no significant differences at 95% were found.

However, relevant differences were found for some factor regarding sex, but only in FE (Table 3).

Significant differences in FE have been found in Abstraction, Audacity, Curiosity and Persistence, where the mean is higher in the group of men for all the cases.

In FE, Pearson correlation among the CREAX test factors was analyzed and relevant correlation ($r > 0.7$) was found in the sample of women among all the factors. However, the group of men shows no relationship between Audacity-Complexity, Complexity-Connection, Audacity-Perspective and Persistence-Perspective. It would be necessary to carry out further studies on this.

FACTOR	TFE	FE
Abstraction	0.83	0.0700
Audacity	0.84	0.0090
Complexity	0.85	0.7500
Connection	0.51	0.3000
Curiosity	0.69	0.0023
Paradox	0.76	0.6000
Persistence	0.55	0.0140
Perspective	0.43	0.4600

C. Analysis of CREAX test correlation –academic performance

No significative correlation was once again found between CREAX test global values and the final mark obtained by students in the subject, but a negative correlation ($r = -0.64$, $p = 0.015$) in women was found considering sex as a differentiating factor, what shows a reverse correlation between the mark obtained in graphic expression and the creativity level measured by CREAX test.

In the assessment criteria applied to vast parts of the subjects Graphic Expression in Engineering, aspects such as systematic operations or compliance with regulations, in which women traditionally excel and which appear contrary to the development and expression of creativity, are indeed boosted. This situation should be further reviewed due to the paradox of promoting in the same subject systematic and inflexibility as well as creativity.

IV. CONCLUSIONS

Some of the conclusions drawn in this work are presented hereafter, although these are only provisional conclusions and further research should be carried out.

There seems to be no relationship between the designed activities and the training sessions in creativity for students, according to CREAX test assessment. However, the assessment suggested shows encouraging results obtained when applying these techniques.

On the one hand, men show a higher global creativity than women. After analyzing the factors, the biggest differences are found in Abstraction, Persistence, Audacity and Curiosity.

On the other hand, women showed more global creativity values, with higher correlation between all the factors and unlike men, who showed no relationship between some pair of factors.

A reverse relationship between academic performance and creativity has been found, but significant differences only concern women once more.

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REFERENCES

- [1] M.J. García-García, et al. "eCompetentis: a tool for evaluation of generic competences", *Revista de Docencia Universitaria*, Vol.8 (n.1) pp. 111-120, 2010
- [2] 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
- [3] M.J. De Teresa, M.J. García-García, G. Dorado, L.J. Fernández, R. Marivela, R.Argüelles, L.F. Mazadiego, A.Tellado. "Edugraphica: eTool for technical drawing self-Learning and self-Evaluation" in *Proc. 2009 ASABE*, Reno, Nevada, June 21 - June 24, cod. 096468
- [4] J. E. Pérez-Martínez, M.J. García-García, W. Hernández Perdomo, 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". In *Proc. 2009 Research in Engineering Education Symposium*. Queensland, Australia
- [5] Documento Propuesta de DECISIÓN DEL PARLAMENTO EUROPEO Y DEL CONSEJO relativa al Año Europeo de la Creatividad y la Innovación 2009. Bruselas, 28.3.2008 COM(2008) Pagina 8. <http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0159:FIN:ES:PDF> (Retrieved April 24, 2011)
- [6] E.P. Torrance, *Torrance tests of creative thinking*. Lexington, MA:Personnel Press/Ginn and Co./Xerox Education Co, 1974
- [7] J.P. Guilford,. "Varieties of divergent production", *Journal of Creative Behavior*, Vol. 18, No 1, pp. 1-10, 1984
- [8] C. Charyton, J.A. Merrill, "Assessing General Creativity and Creative Engineering Design in First Year Engineering Students". *Journal of engineering education*, Vol. 98, No. 2, pp. 145-156, 2009
- [9] E.De Bono,. *El pensamiento lateral: manual de creatividad*. Ediciones Paidós Ibérica, S.A., 2009
- [10] M. Michalko,. *Thinkertoys : cómo desarrollar la creatividad en la empresa*. Ediciones Gestión 2000, S.A., 2001
- [11] Agència de Qualitat del Sistema Universitari de Catalunya (AQU). *Marco general para el diseño, seguimiento y revisión de planes de estudios y programas*. Barcelona, 2002
- [12] G. Wiggins, (1990). "The case for authentic assessment. Practical Assessment", *Research & Evaluation onLine*, <http://PAREonline.net/getvn.asp?v=2&n=2> (Retrieved April 26, 2011)
- [13] L.Villardón Gallego, "Evaluación del aprendizaje para promover el desarrollo de competencias", *Educatio siglo XXI*, Vol. 24: pp. 57 - 76., 2006
- [14] M.M. Clapham, "The effects of affect manipulation and information exposure on divergent thinking", *Creativity Research Journal* Vol 13 No 3-4 pp. 335-50, 2001
- [15] R.J. Sternberg,. *Handbook of creativity*. New York: Cambridge University Press, 1999
- [16] J. Gairín, et al, *Nuevas funciones de la evaluación. La evaluación como autorregulación*. Madrid, MEC. 2009
- [17] K. Tasa, S. Taggar, and G. H. Seijts, "The development of collective efficacy in teams: a multilevel and longitudinal perspective", *Journal of Applied Psychology* Vol. 92, No 1, pp.17-27, 2007
- [18] CREAX NV, test CREAX Creativity Self-Assessment; obtained from <http://www.creax.com/csa/> (Retrieved April 24, 2011)
- [19] E. Ayuga-Téllez; M.J. García-García; C. González-García, R. Argüelles; S. Martín, M.T. Losada and M.J. De Teresa, "Experience in The Teaching of Basic Subjects applied to agrofoestry area" in *Proc. 2006 ASABE*, Portland, Oregon, July 8 - July 12, cod. 068029
- [20] C. Charyton, JA. Merrill, "Assessing General Creativity and Creative Engineering Design in First Year Engineering Students". *Journal of engineering education*, Vol. 98 No 2 pp.145-156, 2009
- [21] C. Charyton, R.J. Jagacinski, and J.A. Merrill. "CEDA: A research instrument for creative engineering design assessment" *Psychology of Aesthetics and Creativity in the Arts*, Vol.2, No 3, pp. 147-154, 2008