ASSESSMENT OF THE ARGUMENTATIVE ABILITY IN INNOVATION MANAGEMENT OF CIVIL ENGINEERING STUDIES

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Abstract

This paper focus in the assessment of the subject Innovation Management in Civil Engineering of the Masters in Planning and Management for Civil Engineering. The subject comprises diverse practical assignments related to the theoretical content on innovation techniques. The evaluation of the course consists of periodical deliveries, which are the object of this paper. A conceptual map is developed by the students to assess its ability for synthesis, which requires certain degree of ripeness and concentration. A specific assessment rubric is used for the assessment. Then, results are compared to the marks of the remaining deliveries. In this respect, these marks are compared to the marks obtained for the Innovation transverse competence. Results manifest that the innovation ability is quite related to the interest of the student on the course.

The assessment of the conceptual map with the four criterion of the assessment rubric shows that there is certain correlation among them. The criteria are: breadth of the net (1), precision of concepts (2), comprehension of concepts (3) and degree of deepness of the topic within the map (4). Further, (3) and (4) exhibit significant correlations with the argumentation of the student's opinion of the topic. Finally, the variability of the evaluated competences regarding the marks of the evaluation map is studied. Thus, the assessment of the argumentation in an opinion question can be explained at a 36.6% by means of an additive regression model.

The featured analysis aims not only to obtain the relationship between the academic performance and the transverse competences, but understand how equivalent the assessed activities are to one another to further improve the course curricula. We can conclude that the use of assessment rubrics looks practical for argument-based assessments, i.e., the professor, in the role of evaluator may incur in a biased judgement because of its own personal opinion.

Keywords: innovation, argumentative ability, conceptual map, postgraduate competences, academic performance.

1 INTRODUCTION

The European Framework of Higher Education regulated the new Graduate studies under the Competence Based Learning (CBS). CBS is subject to study, since its interpretation is still ambiguous. Academic studies were developed on the transverse competence Innovation [1]. Recent work of the group Innovation and Quality Education (EXCELCON) of the University focused on engineering education approach, particularly on the standardization of the innovation process in construction firms [2] and towards social sustainability [3]. Additionally, the group focus on the evaluation of transverse competences such as Critical Thinking [4], [5], [6], design and project and time planning and management [7] and employability of graduates [8]. Nowadays some changes must occur if the engineering and design professions are to remain relevant and responsive to societal needs [9] and sustainable innovative practices [10-17] that require transverse competences to be acquired.

1.1 Generic and Transverse competences

The generic competences must help to develop the greater intellectual abilities based on the studies of Rychen and Salganik [18] respectful of the mental autonomy. On the other hand, Villa and Poblete [19] declare that the generic competitions must help to develop to the higher intellectual abilities such as the critical and the analytical thinking, among others.

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1.2 Levels of Domain and Evaluation Rubrics

Within the context of EEES, Competence Based Learning has been defined as the level of performance or achievement by the studentship, although alternative definitions have been proposed. Given that the domain level of a competence is still ambiguous, a new evaluation approach is proposed, coming from the level of deepness achieved in a competence and the result of the assessment at such level [20].

This communication shows the analysis of the continuous assessment of the student. The purpose is to study the relationship between an exercise of complex assessment; a conceptual map, the transverse competence innovation and other tests. The ability for argument and synthesis has been assessed through a conceptual map [21], whose development requires analytical maturity and concentration to some extent. Some principles of the constructive learning from [22] and [23] are involved in this contribution; the fact of learning has implicit an invite to participate in an active and reflexive way, and a new knowledge gets new significance when it is related to previous knowledge [24]. Both principles are present in the realization of a conceptual map and the development of an innovation project for the course. We will describe next the methodology followed.

2 METHODOLOGY

The completion of optional deliverables is offered as part of the academic weekly tasks. Additionally, the assessment of a transverse competence Innovation is also drawn from the deliverables submitted. Among the evaluative tests, one of the practical assignments consists of the elaboration of a conceptual map about a topic, and subsequent personal discussion on it. This map aims to obtain the synthesis and analytic abilities through argumentation on a written test.

2.1 Evaluation of the Innovation Competence

Innovation, at the basis, is a significant positive change. Innovation entails to introduce something new in a system, by modifying its processes and whose result improves products, what is in the end, the achievement of the goal [25,26]. The domain of this competence is related to attitudes present in other competences, first, creativity, and learning oriented skills, and secondary, problem solving skills and quality-oriented skills. The evaluation is based on the assessment rubric CT-04, Innovation, creativity and entrepreneurship (Table 1), applied on the marks of the exercise of an innovation project developed during the course.

Table 1. *CT-04, Innovation, Creativity and Entrepreneurship*

Indicators	Not reached	Under development	Good/adequate	Excellent
Identify the opportunities and improving aspects	Not identified	Partially identified	Aspects are identified for improvement and opportunities	The risk is correctly identified
Provides ideas and original approaches	No ideas are provided and a passive attitude is shown.	Provides any idea or approach towards new situations	Provides detailed ideas and original approaches	Provides a variety of diverse approaches, and applicable to any case
Uses strategy and/or creative techniques put the solutions in a formal way	No creativity techniques are used	Creativity techniques are used following indications	Creativity techniques are used autonomously	Strategic methods are used fluently to deliver solutions
Check the results	Results are not measured	Results are measured but not analysed	Detailed analysis of results obtained	Deeply analyse of results and conclusions

2.2 Evaluation of the Conceptual map

As seen, the concept of learning implies a re-organization of cognitive structures. By means of a conceptual map, this ability is developed based on previous knowledge in the topic that were formerly acquired [27]. The conceptual map methodology arises from the constructivism teaching-learning process (Ausubel and Novak [21], Bosch [23]). It is a flexible and based in feedback, in opposition to memory-based learning. It is based on the existence of a cognitive structure in the mind, formed over the existing knowledge, over which the new knowledge is built upon [22]. The conceptual map, developed by Novak [21], allows to know whether the student has interiorized in its cognitive structure the new learning, i.e., if a significant learning is made.

Four criteria (A, B, C and D) are considered in the evaluation of the conceptual map; described in Table 2. The evaluated criterion are standardised in the rubric for the assessment of conceptual maps that is valid for professional and academic domains. This rubric aims to assess the critical attitude to reality, being able to analyze, question information, results, conclusions and other points of view. The numeric value for the assessment is granted according to Table 3. As regards the suitability of the level of demand, it is considered that an optimal level of detail in the map can be achieved provided any student develops the exercise notably different respect to the other in the available time.

Table 2. *Evaluation of the conceptual map*

A. Precision of Concepts	B. Degree of Deepness	C. Comprehension of Concepts	D. Breadth of the Net
The use of several concepts of the article that go further of the underlying topic have been positively granted.	The interconnection between concepts, non-evident relationships outsourced from the text. The breath of the net in the shape of tree, with enough hierarchy level which explain the text and its conclusions. The connections make it possible the understanding and constitute arguments to briefly understand the text with a quick glance.	The overall understanding of the map is granted. Easy readiness, visibility and perception of the map as a whole is granted. A hierarchical construct is valued.	The inclusion of concepts and clarifying notes from the student as a result of its readiness comprehension and knowledge of the topic (provided these are not just examples).

Table 3. *Assessment rubric for conceptual map*

Criteria	Excellent (25 points)	Satisfactory (20 points)	Regular (15 points)	Must improve (10 points)
Concepts	The student identified the most important concepts of the text and these are part of the conceptual map.	The concepts that the student illustrates in the map are secondary ideas of the text.	The concepts that the student presents in the conceptual map are only unconnected ideas present in the text.	The map shows vague ideas as concepts
Relationship between concepts	The relationships present in the map are acceptable	The relationships present in the map are moderately acceptable	The relationships in the conceptual map are barely acceptable	The relationships present in the map are not acceptable
Hierarchy	The concepts are logically hierarchical, i.e., the bottom side of the map with subordinate concepts.	The conceptual map only presents inclusive concepts.	The conceptual map presents the subordinate concepts in the upper side of the map, instead at the bottom	Concepts do not show any hierarchy
Propositions	The connectors used with the concepts make an excellent relationship among them to stablish statements.	Not all the connectors used with the concepts are correct, which makes just a relationship.	Many of the connectors used between the concepts are incorrect, which makes a poor relation for statements.	The connectors used are not the right one, so no statements are possible

2.3 Evaluation of the Synthesis skills

This question assess how the main idea of the article is summarized by the student with its. This is carried out as follows: partial conclusions are penalized when these are not framed within the overall idea of the given text. Additionally, conclusions drawn from the text have been positively granted, by building own arguments and also mentioning that there is an investigation to validate the model

proposed by the text (an important aspect that was cited by a minority of the students). The learning process is only granted if the student can explain through the conceptual map, the new knowledge acquired, according to the evolutionary learning theory [28].

2.4 Evaluation of argumentation skills

Another skill evaluated is the student ability for argumentation of its opinion on the topic of the conceptual map, i.e., how can the student support its own built opinion, further than what it is described in the text provided. Additionally, any reasoned argument in favour or against the text has been positively granted. The assessment of this question may be subjective; therefore, the level of conviction of the student answer is assessed. Also the level of knowledge of the issue discussed and the use of vocabulary or generalized examples not being used in the text are also granted, as part of the principles of the constructivism learning theory [22].

3 ANALYSIS OF RESULTS

This section describes the results obtained after the assessment of the academic deliveries, and how some of the assessed tasks can be explained through the rest of the tasks, for which a correlation analysis among these is needed first. From an overall of 36 inscribed students in the course, 32 qualifications are obtained from which 30 are valid in our study. For the sake of the validity of results, 30.6% of the students obtained the qualification excellent, a 52.8% got Above average; 5.6% got Average and 4% did not present the exams. Table 4 shows a summary of descriptive statistics for the course marks.

Table 4. *Descriptive statistics on course marks*

		Innovation TC	Optional Deliveries	Conceptual Map	Synthesis skills	Personal Opinion	Final Mark
N	**Valid**	30	30	30	30	30	30
	Missing values	2	2	2	2	2	2
Mean		7.700	5.900	7.071	7.467	8.190	8.688
Mean standard error		.240	.434	.250	.387	.272	.125
Median		8.000	6.050	6.938	8.000	8.500	8.616
Mode		8.000	3.000	6.250	7.000	9.000	8.282
Standard Dev.		1.317	2.376	1.369	2.117	1.489	.684
Range		5.000	8.300	5.500	10.000	5.000	2.638
Minimum		5.000	2.600	4.500	.000	5.000	7.366
Maximum		10.000	10.000	10.000	10.000	10.000	10.000
Percentiles	**25**	7.000	3.500	6.250	6.625	7.375	8.278
	50	8.000	6.050	6.938	8.000	8.500	8.616
	75	8.000	7.725	8.156	9.000	9.500	9.137

As mentioned, an aspect of interest is the existing correlation among the tests and the tasks. Through the analysis of correlations, the competence Innovation is significant just to the optional deliveries, although with a moderate Pearson correlation coefficient (0.556) (Table 5). Also, the final mark and the optional deliveries are as expected correlated; the students performing better deliver voluntary tasks.

Table 5. *Pearson correlation coefficients of the course marks*

		Innovation TC	Optional Deliveries	Conceptual Map	Synthesis skills	Personal Opinion	Final Mark
Innovation	Pearson	1	.556	.027	-.362	-.035	.363
	Sig. (bilateral)		.001	.889	.049	.854	.049
Optional Deliveries	Pearson	.556	1	.308	-.327	.010	.693
	Sig. (bilateral)	.001		.097	.078	.956	.000
Conceptual Map	Pearson	.027	.308	1	-.124	.292	.198
	Sig. (bilateral)	.889	.097		.513	.118	.294
Synthesis	Pearson	-.362	-.327	-.124	1	.531	-.253
	Sig. (bilateral)	.049	.078	.513		.003	.177
Opinion	Pearson	-.035	.010	.292	.531	1	-.065
	Sig. (bilateral)	.854	.956	.118	.003		.734
Final Mark	Pearson	.363	.693	.198	-.253	-.065	1
	Sig. (bilateral)	.049	.000	.294	.177	.734	

3.1 Analysis through Multiple regression models

Since several correlations among the exercises are found, we perform a regression analysis of all the variables involved to determine the explanatory models of the response variable of our choice. Thus, inferences on simple or multiple linear models are drawn to obtain quantitative measures of the level of correlation of the variables. The linear models adjust by least squares so that the dependent or response variables are explained to the limit by a group of independent or explanatory variables. The goodness of fitness of the model is evaluated by a determination coefficient R^2, deduced as the proportion of variation of the response variables explained through the linear regression model [27].

Thus, each response variable must be explained according to the explanatory variable to which it is more correlated. It is about increasing the regression coefficient by adding independent explanatory variables. To that end, the *forward stepwise* method [28], consist in introducing the variables at a time and check if each variable remains or exits of the model. As a stopping rule (inclusive criterion), an increment in the explained variance F-to-enter value is deemed (F=0.050), while for the exclusion of a variable a drop of 10% (F=0.100) is taken. The first variable introduced is the one with a higher correlation coefficient *R.* Then, all the correlations are again computed by removal of the influence of the variable already into the model. Then the next variable with greater *R* enters the model, in such a way we get the variables entering independent from the ones already in the model.

3.1.1 Transverse Competence Innovation

We analysed the first the Innovation competence as explanatory variable, considering regression analysis as described. Because of a small positive correlation between the competence and the voluntary deliverables, just a 28.5% of the Innovation competence can be explained only through the optional deliveries (Table 6). Residuals exhibit independence by the Durbin-Watson statistical test. As seen in the Introduction section, it is expected that the voluntary deliverables are related with the student willingness for excellent academic results by assignments that, not being part of the academic curricula. The voluntary assignments present the greatest correlation with the Innovation Competence among the rest of the marks, at a 55% of bilateral significance 0.01. Results indicate that the Innovation Competence is related to the effort of the student for the course, as there is a significant correlation with the voluntary assignments submitted. This is likewise verified in [5].

Table 6. *Summary of the model for Innovation Competence*

R	R^2	Corrected R^2	Estimated Standard error	Durbin-Watson
.556	.310	.285	1.1137	2.238

3.1.2 Conceptual map

The conceptual map test consists of three tasks: development of the *conceptual map* (Q1), *Synthesis skills* (Q2) and *Personal Opinion* (Q3). A first inquiry consists of determining whether the subcriteria evaluated in Q1 are correlated to one another. Likewise, we aim to determine correlation of each part of Q1 to questions Q2 and Q3, and to what extent. Fig. 1 shows that student's marks are within the same range among the questions.

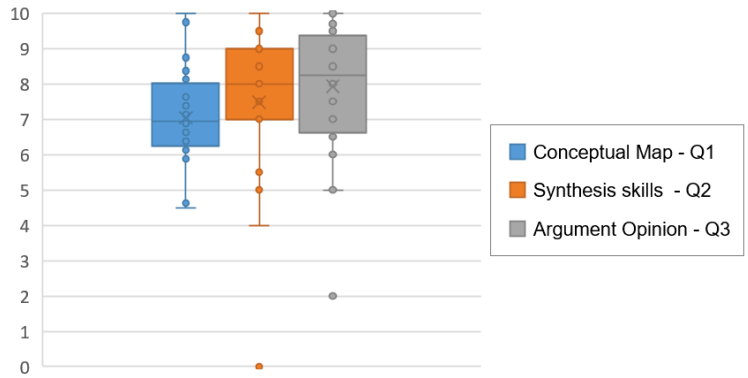

Fig. 1 Average mark at a confidence interval of 95%

A first regression analysis concludes that the mark on the *Conceptual map* can be explained only to a 18.6% by the *Synthesis skills* (Q2) and the *Argumentation of the opinion* (Q3) (Table 7). On the other hand, it can be seen that the *Synthesis skills* can be explained to a 27.1% through the rest of questions through additive regression. Last, the skills for *Argumentation of opinion* (Q3), can be explained to a 36.6% by the *Conceptual map* (Q1) and the Synthesis skills (Q2). Despite the low goodness of fitness of the model, all cases pass the Durbin Watson statistical test. It is worth noting that there is a high subjectivity in this kind of exercises.

Table 7. *Summary of the linear regression model*

Explanatory variable	Model Variables	R	R^2	Corrected R^2	Standard error of estimation	Durbin-Watson
Conceptual Map (Q1)	Q2, Q3	.431[a]	.186	.125	127.351	2.311
Synthesis skills (Q2)	Q1, Q3	.520[a]	.271	.217	139.775	2.051
Argument Opinion (Q3)	Q2, Q1	.605[b]	.366	.319	122.873	2.122

3.1.3 Subcriteria of the Conceptual map (Q1)

An additional analysis is performed, this time we consider the correlation between the subsections in question Q1. Fig. 2 shows that student's marks are within the same range in three out of four subsections. Table 8 shows that the average mark in *Breadth of the Net* is lower. This may respond to a higher revision standard or to other causes such as time devoted to the task.

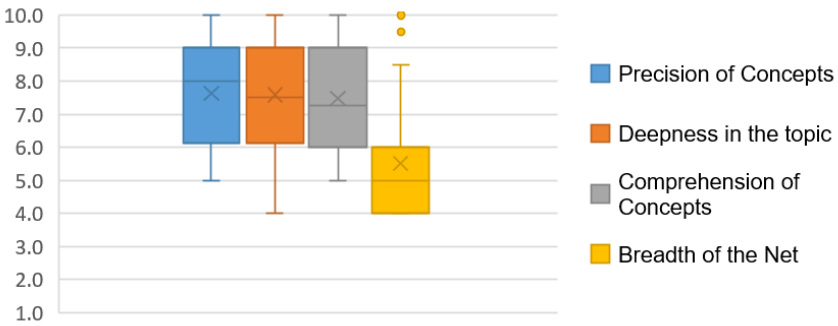

Fig. 2 – Conceptual map evaluation criteria (marks)

Table 8. *Descriptive statistics for the Conceptual map subcriteria*

Criteria Conceptual Map	Average	Standard Deviation
Precision of Concepts	7.625	1.5913
Deepen on the topic	7.578	1.8055
Comprehension of Concepts	7.484	1.7757
Breadth of the Net	5.516	1.8815

Table 9 summarizes the correlations of each subcriteria of the conceptual map, the exhibits some significant correlations to level 0.01 between the fields evaluated when building the conceptual map. The correlations of *Synthesis skills* (Q2) and *Personal Opinion* (Q3) are included. A correlation between Q3 and the field *Deepen on the topic* is found (0.371), as well as the *Level of comprehension of concepts* (0.378), both at 0.05 of bilateral significance. This means that all the six questions assess similar skills, but not equal, so none of them is rescindable.

Table 9. *Correlation of criteria of the Conceptual Map, questions Q2 and Q3.*

		Precision of Concepts	Level of deepness in the topic	Comprehension of Concepts	Breadth of the Net	Synthesis skills	Personal Opinion
Precision of Concepts	Corr. Pearson	1	.523**	.566**	.213	-.013	.081
	Sig. (bilateral)		.003	.001	.259	.944	.669
Deepness in the topic	Corr. Pearson	.523**	1	.460*	.250	.096	.371*
	Sig. (bilateral)	.003		.011	.182	.613	.044
Comprehension of Concepts	Corr. Pearson	.566**	.460*	1	.547**	.055	.378*
	Sig. (bilateral)	.001	.011		.002	.774	.040
Breadth of the Net	Corr. Pearson	.213	.250	.547**	1	-.227	.245
	Sig. (bilateral)	.259	.182	.002		.229	.192
Synthesis skills	Corr. Pearson	-.013	.096	.055	-.227	1	.472**
	Sig. (bilateral)	.944	.613	.774	.229		.009
Personal Opinion	Corr. Pearson	.081	.371*	.378*	.245	.472**	1
	Sig. (bilateral)	.669	.044	.040	.192	.009	

**. Significant correlation to level 0.01 (bilateral).

*. Significant correlation to level 0.05 (bilateral).

A final regression analysis is performed between the six questions (four in the conceptual map, *Argumentation of opinion* and *Synthesis skills*. Table 10 shows a summary of model features (error, standard deviation) for each evaluated field and Table 11 shows the coefficients for the model.

Table 10. *Model statistics features*

Subcriteria Q1	Summary of model			
	R^2	Corrected R2	Standard error of estimation	Durbin-Watson
Precision of Concepts	.408	.364	1.30227	2.778
Deepness in the topic	.387	.316	1.52569	2.027
Comprehension of Concepts	.569	.500	1.28070	*1.829*
Breadth of the Net	.299	.274	1.65387	2.089
Argument Opinion	.381	.310	1.23701	2.177
Synthesis skills	.242	.154	1.45267	2.048

Table 11. *Model coefficients*

Skills (Q1, Q2, Q3)	Constant	Coefficient B					
		Precision of Concepts	Deepness in the topic	Comprehension of Concepts	Breadth of the Net	Personal Opinion	Synthesis skills
Precision of Concepts	2.638		.373	.295			
Deepness in the topic	-.062	.502	.097			.370	
Comprehension of Concepts	-.912	.488		.047	.359	.279	
Breadth of the Net	1.136		0.586				
Personal Opinion	2.164		0.211	.170			.412
Synthesis skills	4.168		-.111	-0.038		.568	

4 CONCLUSIONS

This paper aims to evaluate several skills of graduate students such as the capacity for synthesis, the Innovation competence and the ability to create a conceptual map. We have turned to the corresponding assessment rubric and later estimation by additive regression models. The assessment of the map unveils that, besides there is a significant correlation between two of the evaluated fields, there is a correlation with the assessment of the personal opinion of the student. These fields are the *Deepen of the topic* and the *Level of comprehension of concepts.*

Additionally, the results of the evaluated tasks have been compared with the Innovation Competence Because of the subjective nature of the logical skills implied in this Competence, the assessment of the competence is carried out through an evaluation rubric to quantify such skills in a knowledge domain level I, in an essentially engineering course. Likewise, the evaluation of the Conceptual map also requires a rubric. In the study it is observed that the argumentation of an opinion question can be explained at a 36.6% by multiple regression of the assessment map (Q1) and the *Argumentation capability*. Likewise, certain correlation exists between the *Deepen of the topic* and the *precision of concepts*. This may be partially due to a greater or lesser interest of the student for the correctness during the conceptual map as well as to the influence of the evaluator on the assessed mark, because he/she plays an active role of the assessed matter.

There is clear correlation with the student effort for the course. One might expect that the optional deliverables are related to the student willingness for an excellent academic performance further than the mandatory deliverables. The low correlation may indicate that there are external factors that explain variability, and cannot be gathered in the regression model. This is consistent with the fact that the effort and attitude of the student towards the course influences the model results. Thus, the use of assessment rubrics is highly recommended. The assessment through an evaluation rubric becomes a practical method to obtain the evaluation of argumentative-like activities. The teacher, in its role of evaluator, might find it difficult to extract the value to assess without introducing a natural biased due to its personal opinion. The featured analysis aims not only to obtain the correspondence between the academic performance and the transverse competence, but also to know how similar the evaluated tasks are to one another. It would improve the course curricula.

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