CORRELATION BETWEEN PROCEDURAL AND CONCEPTUAL TEST IN A STATICS COURSE

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***Abstract*—Due to poor performance in Statics at Eafit University, since 2012 the Mechanical Engineering department implemented a virtual tool for the training and assessment of Statics course. Although the implementation led to better performance in the Statics course, students were still showing lack of comprehension of the basic concepts underlying the subject. The department applied a Concept Inventory test to 195 students from the second semester of 2017 in order to check if there was a correlation between the grades obtained in the class examinations and the performance in a conceptual test of Statics. The Concept Inventory was applied one week before the final examination and it was held inside the University facilities. The students were monitored all the time. For the course examinations were taken only three out of the four partial exams, they were computed and then compared to the results of the concept inventory. The results show that almost all the students with the highest grades in the class performed above the mean in the Concept Inventory. The overall mean for the conceptual test was 9.27 and the standard deviation was 5.28. The course grades were discriminated by career and an Analysis of Variance was conducted to determine if there were significant differences among the groups. A correlation analysis suggests that there is not a strong correlation between the course grades and the concept inventory results. One possible explanation for this can be due to the fact that the regular teaching method for these kind of basic courses in engineering in the University is merely procedural and problem-solving oriented, conceptual approaches are often neglected in both teaching and assessment.**

***Index Terms*—concept inventory, Statics, engineering education.**

I. Introduction

Teaching is an important and complex task to perform in different contexts in life. In engineering education, this is a delicate process, because the future generations of engineers will be facing complicated problems in the society, so today's students must be competent to address those problems successfully. For this reason, professors need to make sure that all the knowledge they're willing to transmit to the students is in fact being retained in students' minds.

Although nowadays there is an increasing tendency of considering the conceptual approaches for teaching in engineering [1]–[3], teaching tends to be very procedural in basic courses in engineering, students are often asked to solve practical problems that requires procedures and algorithms predefined. Even though in engineering the use of numbers and calculations must be strict, those by themselves, are not sufficient to guarantee that a student has actually acquired the knowledge involved in the subject. Sometimes, students tend to memorize processes and algorithms to get to an answer in a specific problem but it does not mean they completely understand the interactions among the variables at stake.

Another important issue concerning the education in engineering is the instrument used for assessing the students' performance. Evaluation is strictly attached to the teaching and learning processes, so it is important to design the best possible instruments to give a just feedback and to self-evaluate the teaching strategies in the classroom [4]. One of the more meaningful efforts made in this sense are the Concept Inventories (CI's). CI's compile several small independent concepts into a single test format, these concepts are supposed to measure the conceptual ability of a student in a given subject. CI's are also very valuable to determine the most common types of errors of students when taking a test, this at the same time, constitutes a precious source of information for the design of teaching strategies. The Statics Concept Inventory has been validated before [5]–[7] so it was chosen for this study.

At Eafit University, Statics makes part of the mechanical engineering department. From year 2012 it was implemented a Learning Management System (LMS) in Statics with the aim of reducing the number of course lost and cancellation. Although the implementation has helped in this sense [8], professor of subsequent courses have expressed a concern about the lack of Statics concepts by students.

Because of the above, the university decided to assess this issue through a conceptual test in order to determine if students possessed good conceptual understanding of Statics. In this paper will be compared the students class grades with the performance of the students in the CI.

II. Methodology

All of the statics classes were taught in-person during 16 weeks. Different topics (see Appendix 1) were taught from

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week 1 to 3, in week 4, the class was dedicated to prepare the students for the first partial examination and to answer doubts about the different topics. Students had to take weekly quizzes about the content of the previous week. This scheme was repeated throughout the semester, so for example, from week 5 to 7, students were taught different subjects and on week 8 the class was again dedicated to solve some preparation exercises and to clarify doubts the students had. The suggested books for students in that semester was Beer's book [9]. Nevertheless, during semesters 2014-2, 2015-1 and 2015-2 a survey was conducted and it was found that only about 7% of students make use of any book to study, and that they rather use a virtual platform implemented in the university [8].

For the second semester of year 2017, the Statics course consisted of four partial exams, each of 15% weight in the overall grade, a final examination with a weight of 20% and finally, weekly quizzes (13 in total) that had the 15% remaining weight to complete 100% of the course grade. The weekly quizzes were presented on the virtual platform and students could take them from any place they wanted. However, there was a specific hour and day to take it, for semester 2017-2 that was set to be on Fridays at 6:00 pm. For the case of partial exams, the three first ones were conducted online as well. The partial exams could only be taken inside the University facilities in a specific computer room and students were monitored all the time by professors' assistants and the teachers themselves. The fourth and the final examination were conducted as paper-and-pencil tests, this is cause in the last two exams the students were asked to draw properly the shear-force and bending moment diagrams. For all the exams, including the quizzes, the grades range from 0.0 to 5.0, and students need to get 3.0 in the overall course grade in order to approve it.

A. The Virtual platform

The Evaluation System is a web tool which is used by the university since year 2012. It was created as a training system but then evolved to an evaluation system as well. It is currently implemented in Moodle, a well-known Learning Management System which supports a variety of functions to manage learning successfully. The data base of exercises is fed through XML Moodle files that are created in JAVA language. Those exercises are programmed to be partially-dynamic and for some of the topics in the course, the exercises are entirely dynamic, meaning that they are drawn, calculated and generated automatically.

B. Partially-dynamic exercise

The type of exercises consists in a fixed image in which the distances, angles, forces and moments are shown as variables whose values are only presented in the statement of the exercise as it can be seen in Fig.1.

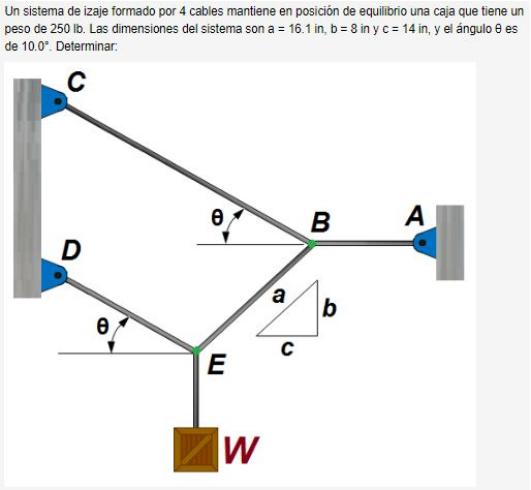

Fig. 1. Partially-dynamic exercise - Equilibrium in 2D

In the exercise[1] the values of "theta", "a", "b", "c" and the weight "W" vary every time that the students access this exercise. For every topic of the course there are around 20 to 25 exercises for students to practice. Each semester, new exercises are added. The variation of the values is helpful to avoid the exchange of information when the students are taking a test.

C. Dynamic exercises

This type of exercises consists in an image that varies every time the student accesses the exercise. Most of the components in the image are re-arranged and the values of forces and distances are calculated each time. In Fig.2, can be seen an example of this exercises.

When a student accesses the problem is presented with a different configuration of the exercise[1]. In the problem shown, the possible variations could be: type and number of loads, magnitude of loads, position of loads, and position of connections, overall length and number of sections of the beam. With all those variations, the students can study different configuration in beams.

D. Concept Inventory

The Concept Inventory used [10] is a test composed of 27 questions about the main concepts in Statics. The test is clustered in 9 groups as it follows: Forces on collection of bodies, Newton's third law, Static equivalence, Roller, Slot, Negligible friction, Representation, Friction and Equilibrium. In each of these categories there are three exercises. However, in previous applications of the test was found that the Item 26 was presenting malfunctioning so two new items were added to this group. It was also added a third item in the category

[1]A systems is composed by 4 cables that maintain the a 300 lb box in equilibrium. The dimension for the systems are a = 16.1 in, b = 6 in, and c = 15 in, and angle theta is 35, determine:

[1]The beam has a fixed support and a pin support. The beam is loaded as show in the figure

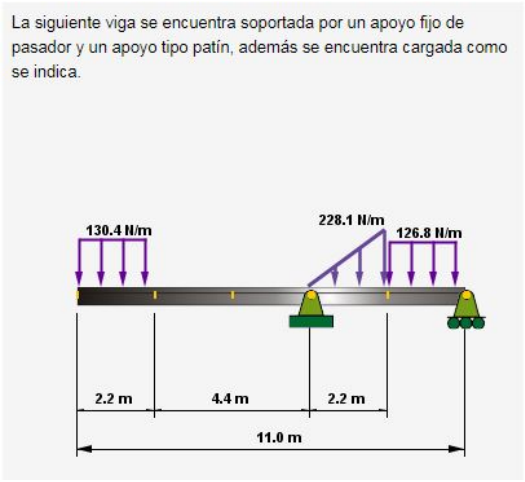

Fig. 2. Dynamic exercise - Beams

of Forces on collection of bodies, this due to the fact that any of the existent problems took into account the representation of friction forces in the free-body diagram. The modified test was then composed of 30 items.

The Conceptual Inventory was translated into Spanish and the students took a Computer-based version of the test. The test was uploaded to the same platform (Moodle) since the students already had access to it from day one of classes. An email was sent one week prior the final examination inviting the students to take the test. Attached to the email was a suggested schedule for the different groups to take the exam. The test was voluntary, although students who took it received a bonus on the final exam's grade. The bonus was proportional to the grade obtain in the conceptual test and it never exceeded 1.0. The test could only be taken inside the university facilities, at the place and hour suggested in the email. Students were monitored while doing the exam, this to make sure they did not share. The duration of the exam was set to 60 minutes.

III. Results

From all the grades of the statics course only the ones corresponding to partial exam 1, 2 and 4 were taken into consideration for the analyses, this is cause, for the partial exam number 3 a bonus was offered to all the students who attended and presented some homework activities about an important congress who was being held in the university in those days. The final examination also had the results altered due the fact explained above. Since the quizzes were not monitored and students could take them from anywhere they wanted, those results were not valid to represent the students' level in Statics, and so they were not included in the analysis either.

A total of 280 students were enrolled in Statics during the second semester of year 2017, from those, only 238 took all the course examinations and 195 took the conceptual test. Students who completed both, the course exams and the CI, were 188. From that last group, women constituted the 26% (49 students) and men were the 74% (138 students). In table I can be seen that there is not a significant variation between women in men for the course grades obtained through the examinations. The Ci's results show that men responded in overall two more questions than women, this difference is not significant since the SD for the conceptual test was almost 5.

The values for the mean and SD discriminated by career are presented in tableII. In order to know if there were statistical significant differences between the groups of students an ANOVA analysis was performed. First, the ANOVA assumptions needed to be verified. To verify the assumption of normality, two test were conducted, the Jarque-Bera test [11] and Shapiro-Wilk test [12]. For the assumptions of homoscedasticity a Levene's test [13] and finally, to verify independence the Durbin-Watson test was used [14]. In tableIII can be found the p-values for each of the tests mentioned.

The null hypothesis for the normality test states that the data comes from a normal distribution. The null hypothesis for the Levene test is that variance for the three groups is equal.

Once the assumptions have been verified, an ANOVA test was conducted to check if there were any statistical significant differences between the means for each group. In table IV can be seen the result for the analysis.

Since the p-value obtained is bigger than 0,05 we cannot reject the null hypothesis meaning that there are not statistical significant differences among the groups.

As it was mentioned before, only 188 students had all the information the analysis. In order to know if there was a correlation between the grades in the course and the ones

TABLE I
COMPARISON COURSE GRADES AND CI

Course Examinations			**Concept Inventory**	
Students	***Mean***[a]	***Percentage***	***n***[b]	***Percentage***
Women	3,39	67,7%	8,33	27,8%
Men	3,49	69,7%	10,42	34,7%
Total	3,46	69,2%	9,87	32,9%

[a]The maximum grade in the course examination was 5.0.
[b]The n represents the mean of the number of correct responses out of 30 in the CI.

TABLE II
COURSE AND CI'S GRADES DISCRIMINATED BY CAREER

Course Grades				**CI**
career	***n***	***mean***	***SD***	***mean***
Mechanical Engineering	55	3,4	1,40	12,09
Civil Engineering	108	3,43	1,26	8,94
Production Engineering	24	3,71	1,4	8,96

TABLE III
VERIFICATION OF ANOVA ASSUMPTIONS

Test	*Statistic*	*p-value*
Jarque-Bera	JB = 1,873	0,3435
Shapiro-Wilk	W = 0,988	0,1373
Levene	F = 2,025	0,1349
Durbin-Watson	DW = 2,002	0,509

TABLE IV
ANALYSIS OF VARIANCE

	df	*Sum Sq*	*Mean Sq*	*F value*	*p-value*
Career	2	352,5	176,262	2,558	0,08
Residuals	184	12680,1	68,914		

obtained in the concept inventory it was drawn a scatter-plot between the two variables. In Fig 3 can be seen the scatter-plot. If there was a correlation, for high values in the course's grades would be expected high values in the CI, as it is evident, there is not a correspondence for these two variables. In fact, the students who had low scores in the course examinations, had surprisingly high values in the CI. The overall comparison suggests that it does not exist a strong correlation between course examination and the concept inventory. To verify that, a Pearson correlation test was made between the grades in the course and the CI's. In tableV can be seen the matrix.

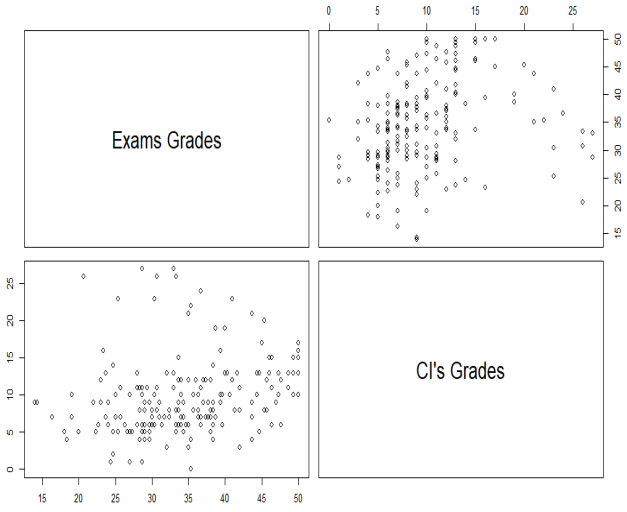

Fig. 3. Scatter-plot CI's grades and Exams

TABLE V
PEARSON CORRELATION

	Exams	*CI*
Exams	1	0,2445
CI	0,2445	1

IV. DISCUSSION AND CONCLUSIONS

The ordinary approach for teaching Statics at Eafit University is based on procedural problems rather than conceptual ones, in fact, none of the exercises in the LMS system consider conceptual problems. Most of the people could argue that when students solve practical problems are making use of the concepts underlying the problem, but that is not necessary true, sometimes students get used to apply a method or to follow steps to get to the answer. This can be unfavorable in the near future when taking more advance courses in their careers or later when facing a real engineering issue in a job. Because of this, it is relevant to assure that students are not only capable of following procedures to get a correct answer in a test, but to provide a deep explanation of the concepts in which those concepts are based on.

It can be concluded from this paper that the overall performance in the course grades does not have a direct correlation with the performance in a concept inventory.

Approaches merely procedural in teaching can lead to a lack of deep understanding of the concepts underlying basic core courses in engineering, meaning that, focusing the teaching strategies only on procedures may lead the students be so ingrained in just following steps rather than use critical thinking to solve conceptual problems.

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