COMPARISON OF DIFFERENT TYPES OF ACTIVE LEARNING IN A COURSE OF INDUSTRIAL ENGINEERING

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ABSTRACT

In accordance to CDIO, active learning methods engage students directly in thinking and, currently, the application of innovative learning tools in the engineering courses are becoming mandatory. The selection of the most appropriate methodology for each course is a challenge. Once CDIO adopts that assessment of student learning is the measure of the extent to which student achieves specified learning, the outcomes from the assessment can be adopted as one indicator giving the direction to the better choice of methodology. In this research, three innovative methodologies were applied with a group of 81 undergraduates belonged to an industrial engineering course. During one semester were collected the outcomes data of the assessment applying to the group using: Team-Based Assessment, Peer Assessment and Project-Based Assessment. The data were treated using ANOVA, Tuckey multiple comparisons and the paired t-test in order to validate the hypothesis that the average grade of the group after each type of assessment would be the same considering the three methodologies. The findings were discussed and presented. The work was concluded and opportunities for further researches were suggested.

KEYWORDS

Assessment, team assessment, peer assessment, industrial engineering course, project-based learning, standards: 7,8,11.

INTRODUCTION

As students are not all alike and have different expectations regarding their higher education experience, the school should provide different learning processes somehow adapted the students' profiles. Nevertheless, there are several constraints:

1. School's internal pedagogical regulations, which strongly limit the existence of different assessment paths in a course.
2. Outcomes-based program accreditation processes, which require that a minimum set of outcomes must be the same for every student. Thus, different learning processes must have the same outcomes.
3. Students usually prioritize their effort, so coursework that does not contribute to the course's grade is usually given a very low priority or left undone.

Removed from CDIO standards (standard 11): "Assessment of student learning is the measure of the extent to which each student achieves specified learning outcomes. Instructors usually conduct this assessment within their respective courses. Effective learning assessment uses a variety of methods matched appropriately to learning outcomes that address disciplinary knowledge, as well as personal and interpersonal skills, and product, process, and system building skills. These methods may include written and oral tests, observations of student performance, rating scales, student reflections, journals, portfolios, and peer and self-assessment. If we value personal and interpersonal skills, and product, process, and system building skills, and incorporate them into curriculum and learning experiences, then we must have effective assessment processes for measuring them. Different categories of learning outcomes require different assessment methods. For example, learning outcomes related to disciplinary knowledge may be assessed with oral and written tests, while those related to design-implement skills may be better measured with recorded observations. Using a variety of assessment methods accommodates a broader range of learning styles and increases the reliability and validity of the assessment data. As a result, determinations of students' achievement of the intended learning outcomes can be made with greater confidence." (CDIO, 2016).

Regarding this, we thought that Integrated Learning Experiences (standard 7), Active learning (standard 8) must be dominant in a CDIO program.

Also, different things to different people, so that it would be useful to have a reference/catalog for active learning methods. Based on this, methodologies as Team-based learning (TBL), Peer (standard 11) (PA) and Project-based learning (PBL) are being applied by the universities worldwide.

TEAM-BASED LEARNING (TBL) AND TEAM-BASED ASSESSMENT (TBA)

Team-Based Learning is an evidence-based collaborative learning teaching strategy designed around units of instruction, known as "modules," that are taught in a three-step cycle: preparation, in-class readiness assurance testing, and application-focused exercise. A class typically includes one module.

TBL has been adopted by schools, in order to develop the students' abilities to solve engineering problems (Borrego et al., 2013), as well as the development of transversal skills (Conway et al., 1993).
Maynard and Sanchez (2013) used a Crazy Machine with teamwork and verified that the experience gave students the opportunity to develop professional skills and learn about the design embedded system, encouraging students to reflect more in their learning and how it happened (or not).
Truong et al. (2014) using data collected during the deployment of CDIO's Capstone Projects, measured, assessed and analyzed the maturity levels of the student's teamwork capabilities. Based on their "in-house" rubric, which addressed key aspects of teamwork capabilities along five dimensions of (1) Shared leadership, (2) Team orientation, (3) Effort redundancy, (4) Learning results and (5) Team's autonomy.
In this research work, one of the applied assessment methods was the TBA, where the students had an examination conducted in a group with a maximum of six members regarded to the theoretical concepts of the discipline. In the group, each student had one different examination from the others and they had helped themselves to address the examination questions.

PEER ASSESSMENT (PA)

Peer assessment, in which students evaluate each other's work, has been defined as an arrangement for individuals to consider the amount, level, value, worth, quality or success of peers' learning products or outcomes (Topping 1998).
Peer assessment is a reflexive learning activity. It increases the students' time to the task and can help them consolidate, reinforce and deepen their understanding by letting them experience reviewing, summarizing, clarifying, giving feedback, diagnosing misconceived knowledge and identifying missing knowledge (Wengrowicz, Dori & Dori, 2017).
Thomson, Spooner & Chalashkanov (2015) presented evaluations of the performance of students on multiple peer review projects over their curriculum and also surveys students' perceptions and experiences on the use of peer assessment among students.
In this work, PA was conducted considering that individual student had to evaluate their peer' outcomes. The outcomes were regarded to assimilation of the content of the discipline.

PROJECT-BASED LEARNING (PBL) AND PROJECT-BASED ASSESSMENT (PBA)

The teaching role in PBL is changed. The teacher is no longer the expert lecturer, facts provider, and director of instruction but rather a resource provider, learning environment shaper, how-to-learn teacher, advisor, tutor and colleague (Buck, 2018). Krajcik, Czerniak and Berger (1999) suggest three possible advantages for the teacher. Firstly, the teacher may find the work enjoyable, interesting and motivating, since teaching will vary every year, as he/she will be exploring new projects with each new group of students. Secondly, in project-based teaching, the teacher continually receives new ideas, thus becoming a 'lifelong learner'. Thirdly, classroom management is simplified because when students are involved, they are likely to cause fewer disciplinary problems.
Frank & Barzilai (2004) described in their work that three challenges were experienced by the students when they were submitted to PBL methodology: coping with conflict situations in the teamwork, investing a lot of time and efforts, and coping with new contents in a learning environment which is neither structured nor organized in advance.

In general, students and teachers have been satisfied with the new learning process. Students think that the projects have now better “real working life feeling” than before. The new process is more meaningful, and its clear description tells who shall do what and when. Students particularly like the new way of setting learning goals for the project together with the project group instead of each student filling in a learning diary monthly (Määttä, Roslöf & Säisä, 2017).
In our research work, PBA was conducted in the same groups of six members, where each group had to presented the final project to be evaluated, delivered one scientific article based on the project and one member from each group was randomly drawn to realize one examination about questions regarded to their group projects.
This paper aims to validate the hypothesis that the results originated from the assessment from the three methodologies, TBA, PA, PBA, were the same.
The results were quantitatively analyzed and commented, followed by suggestions for further researches.

APPLICATION AND FEEDBACK

TBA, PA and PBA has been applied, to eighty-one students, during one semester in one Industrial Engineering Course, having The Plant Design as the subject discipline. When the teacher understood, theoretical classes were conducted.

Research procedures

To apply these methodologies, the students were divided into groups with a maximum of six students.
First, the teacher presents the project, the assessment procedures, the content and importance of some meetings and the weighting of the final grade.
Second, under the teacher supervision, they define a timetable of the Project with the activities, responsibilities, date for begin and end of each part of the project.
To follow up on the project throughout the semester, there are meetings with the teacher throughout the semester.
During the semester, we apply:

1. **TBA assessment**: They work together, but each member has a different exam;
2. **PA assessment**: After one month of the previous assessment (TBA), each student is assessed individually by his peer;
3. **PBA assessment**: Here, the students present the final project. The assessment consists of presenting a report in the format of a scientific paper (50% of the final PBA grade), followed by presentation by the group (30% of the final PBA grade) and defense of it by one of the members, randomly drawn, of the group (20% of the final PBA grade).

FINDINGS AND DISCUSSIONS

We want to know if there is a significant difference between the averages obtained by the students, depending on the three methods used (TBA, PA and PBA).
For this, a Variance Analysis (ANOVA) was used, with classification and samples of the same size.
The null hypothesis to be tested, of equality between the three means and the alternative hypothesis, can be presented as follows:

H0: $\mu_{TBA} = \mu_{PA} = \mu_{PBA}$
H1: there is at least a different average

The summary of results and the table of analysis of variance are presented in Table 1 and Table 2, respectively:

Table 1. Summary of ANOVA results

Groups	Count	Sum	Average	Variance
TBA	81	607	7,49382716	3,36558642
PA	81	676,5	8,351851852	3,402777778
PBA	81	645	7,962962963	1,561111111

Table 2. ANOVA test results

Source of Variation	Sums of Squares	Degrees of freedom	Mean Square	F-Values	P-Value
Between groups	29,9033	2	14,9516	5,3851	0,0052
Within groups /Error	666,3580	240	2,7765		
Total	696,2613	242			

The P-value found is much lower than the usual significance levels. This indicates the existence of a significant difference between the 3 methods.
The ANOVA identified a difference between means, but the question remains: which average (s) should be considered different from what other(s)? In principle, the PA method seems to be the largest and the TBA method is the smallest, but it is necessary to continue the analysis because it can be concluded from the difference among the three means or two or two partial differences. To do so, we decided to use two methods: the Tuckey multiple comparisons and the paired t-test applied between the samples, two by two.
Because the samples are the same size, the Tuckey method is efficient. This method uses critical values of the standardized amplitude, denoted by q. The literature provides critical values of q in the case of a normal population. If we want to compare k samples, each of them with n elements, the procedure recommends considering the means μ_i e μ_j as distinct:

$$|\bar{x}_i - \bar{x}_j| > q_{k,\upsilon,\alpha}\sqrt{S_R^2/n}\,, \quad (1)$$

Where: α is the desired level of significance, $\upsilon = k(n-1)$ e S_R^2 is the residual variance.
For the case under analysis, we have: n=81; k=3; S_R^2=2,78. And adopting the significance level of 5%, we must use q_(3,240,5%)=3,33. Averages of more than 0.62 should, therefore, be considered different. The results are:

$$\begin{aligned} |\bar{x}_{TBA} - \bar{x}_{PA}| &= 0{,}86 \\ |\bar{x}_{PA} - \bar{x}_{PBA}| &= 0{,}39 \\ |\bar{x}_{PBA} - \bar{x}_{TBA}| &= 0{,}47 \end{aligned} \quad (2)$$

That is, the averages of the TBA method and the PA method are considered different from each other. Better: the average PA is bigger than the TBA. In addition, taken two by two there seem to be no significant differences: between PBA and TBA and between TBA and PBA.
But by this method, it is not possible to know from what level of significance it can be said that there is a difference between these means. For this, the t-test was applied, with paired samples, two by two. Student identity is the criterion for matching the data. The t-test is used to compare two means with each other.
When the data from two samples are paired, it makes sense to calculate the di differences corresponding to each pair of values and test the hypothesis that the difference between the means of the two paired populations is equal to a certain Δ value. This is equivalent to testing the hypothesis that the mean of all differences for populations is equal to Δ.
That is, we will simply test the hypothesis H0: μ_d = Δ against an H1 alternative that may correspond to a unilateral or bilateral test, depending on the interest. The test value will be the Student t test that will be compared with the critical value of Student t obtained as a function of the level of significance with n - 1 degree of freedom. Or a complementary procedure that is to analyze the p-value corresponding to Student's t experimental. It is therefore calculated:

$$t = \frac{\bar{d}-\Delta}{S_d/\sqrt{n}} \quad (3)$$

at where:
($\bar{d}$)is the mean of the sample of differences,
Δ is the tested value of the mean of the differences in populations, which will be zero when testing equality
S_d is the sample standard deviation of each method
n is the sample size of the differences
Summary, we have the desired and realized tests, thanks to the pairing of the data, which are shown in Table 3.

Table 3. Conducted t-tests

Test initially desired	Test performed, thanks to pairing of data
H_0: $\mu_{TBA} = \mu_{PA}$ H_1: $\mu_{TBA} \neq \mu_{PA}$	H_0: $\mu_{d1} = 0$ H_1: $\mu_{d1} \neq 0$
H_0: $\mu_{TBA} = \mu_{PBA}$ H_1: $\mu_{TBA} \neq \mu_{PBA}$	H_0: $\mu_{d2} = 0$ H_1: $\mu_{d2} \neq 0$
H_0: $\mu_{PBA} = \mu_{PA}$ H_1: $\mu_{PBA} \neq \mu_{PA}$	H_0: $\mu_{d3} = 0$ H_1: $\mu_{d3} \neq 0$

The t-tests were performed using Microsoft Excel ® software, using the "t-test: two paired samples for averages", available in "Data analysis". The summary of results is shown in Table 4.

Table 4. t-tests results

	H_0: $\mu_{TBA} = \mu_{PA}$		**H_0: $\mu_{TBA} = \mu_{PBA}$**		**H_0: $\mu_{PBA} = \mu_{PA}$**	
	Team	***Peer***	***Peer***	***PBL***	***PBL***	***Team***

average	7,4938	8,3518	8,3518	7,9629	7,9629	7,4938
variance	3,3655	3,4027	3,4027	1,5611	1,5611	3,365
observations	81	81	81	81	81	81
difference hypothesis	0		0		0	
degrees of freedom	80		80		80	
Student's t experimental	-3,204347501		1,898141506		1,883127441	
p-value uni-caudal	0,000972467		0,030642028		0,031658786	
t critical uni-caudal	1,664124579		1,664124579		1,664124579	
p-value bi-caudal	0,001944935		0,061284056		0,063317572	
t critical bi-caudal	1,990063421		1,990063421		1,990063421	

From these results, especially by analysing the p-values, one can conclude that the data are compatible with the mean difference, with strong or moderate evidence, as summarized in Table 5.

Table 5. Summary of t-tests results

	PA	**PBA**
TBA	Single p-value = 0.0010 Two-tailed p-value = 0.0019 It is concluded that the results are compatible with the difference between the averages (strong evidence)	Single p-value = 0.0317 Two-tailed p-value = 0.0633 We conclude that the results are compatible with the difference between the means (moderate evidence)
PA		Single p-value = 0.0306 Two-tailed p-value = 0.0613 We conclude that the results are compatible with the difference between the means (moderate evidence)

It is seen that such results are always compatible with the difference between the three means, although in different degrees of intensity in the certainty of these conclusions.
The results obtained by the two methods (Tuckey method and two-two t-test) are compatible and can be synthesized as follows:

$$\mu_{PA} > \mu_{PBA} > \mu_{TBA} \quad (4)$$

CONCLUSIONS

The purpose of this research work was reached by the demonstration that the average of the outcomes obtained from the assessments data from the TBA, PA and PBA was not the same, which demonstrated that the hypothesis H0 was not true.
As a practical implication, this work can be used as a guide for professors who are looking forward to applying one of these three innovative methodologies as an alternative to the conventional assessment approach.
This research work presents limitations as (1) The results were obtained from Industrial Engineering Course only, as well as from one specific discipline, (2) The significance value adopted was 0.5% to reach the F-Critical value which can change if a higher significance value would be adopted, changing the results.

As further researches it is recommended that the same approach using the three methodologies could be applied in a different course, for example, Business Administration, and ANOVA, Tukey and t-test analysis could be conducted for the comparison of the results, adding one more significant value to reach the F-Critical in order to validate or not the H0 hypothesis.

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BIOGRAPHICAL INFORMATION

Cleginaldo Pereira de Carvalho, Post PhD in Industrial Engineering by University of Sao Paulo, Post PhD in Industrial Engineering by University of the State of São Paulo, Ph.D. in Mechanical Engineering by University of the State of São Paulo. Professor and Researcher in the Industrial Engineering Department of the University of the State of São Paulo. Professor in the Faculty of Human Sciences of Cruzeiro and in the Faculty of Technology of Pindamonhangaba. With years of experience as an Industrial Director in the corporate world, he incorporates his background onto his current research, which focuses on Learning Innovation, Lean Manufacturing, Knowledge Management and Industry 4.0.

Eduarda Pinto Ferreira, has a PhD in Engineering Science (2006), a Master in Electrical Engineering – Telecommunication profile (1995) and Bachelor in Applied Mathematics and Computer Science (1991). She is Adjunct Professor in ISEP's Mathematics Department where she lectures since 1992 in several programmes and courses. Has co-supervised 2 PhD theses. She was President of the Pedagogical Council between 2010 and 2014. Since 2018 she is Director of the Master in Development Practice at ISEP and an active member of the Student Learning Assessment group of the CDIO She is member of Academic Program Committee of CSD&M, Paris, 2018 She is Coordinator of Euclides network. She is Coordinator of the Engineering Education Research line at the Interdisciplinary Studies Research Center - ISRC She was awarded with the prize for Pedagogical Innovation in Distance Education She has several publication in education research area.

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