Effects of Introducing an Interactive Teaching and Learning Activity (TLA) in the Engineering Classroom

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***Abstract*—This research study examines qualitatively and quantitatively the influence of introducing an activity in the traditional engineering classroom. It studies instances of active learning and its relationship with the student learning outcomes. The primary purpose of this study was to compare the learning outcomes of students who were involved in an active TLA with those students who were not, instead they learned under traditional teaching and studying approaches. I present the argument that the introduction of a TLA in class stimulates student engagement bringing enormous benefits to student learning. The outcomes of this study were measured using qualitative and quantitative data to evaluate the levels of student engagement, achievement and satisfaction in the terms of Intended Learning Outcomes (ILOs). Results indicate that students held positive attitude towards the activities in class and also, that a positive link between TLA, learning approach and learning outcome exist. It also provides insights about the potential benefits of active learning when compared with traditional, passive and teacher-centred methods of teaching & learning.**

***Index Terms*—active learning; engineering critical-thinking; student-centred learning**

I. Introduction

In the university education arena, it is becoming apparent that traditional methods of conducting classes are not the most effective ways to achieve desired learning outcomes. The traditional class/method involves the instructor verbalizing information for passive, note-taking students who are assumed to be empty receptacles waiting to be filled with knowledge. This method is limited in its effectiveness, as the flow of information is usually only in one direction.

The literature supporting the notion that active, student-centered learning is superior to passive, teacher-centered instruction is encyclopedic [1], [2], [3], [4], [5], [6], [7]. Previous research have suggested that introducing a simple activity in class improved the learning outcomes of students [8]. People acquire knowledge and skills through practice and reflection, not by watching and listening to others telling them how to do something.

Furthermore, *"It has been demonstrated that students in many cases can recite and apply formulas in numerical problems, but the actual meaning and understanding of the concept behind the formula is not acquired [9]"*. It is apparent that memorization is the main technique present in this approach.

A more effective method of teaching involves increasing the students level of activity during class, and hence their involvement in the learning process. This technique stimulates self-learning and assists in keeping these students' levels of concentration more uniform.

In this work, I am therefore interested in studying the influence of a particular TLA on students learning-outcomes. I want to foster high-level understanding and critical thinking skills using active learning techniques [10]. The TLA in question aims to promote self-study by students and to expose them to a situation where their learning-outcomes can be tested. The student assumes the role of the lecturer. The motivation behind this activity is based on studies that suggest that some sensory modalities are more effective than others. A study attributed to William Glasser taken from [11] indicates that *most people learn of what they teach someone else*.

A diagrammatic representation of this statement is shown in Figure 1.

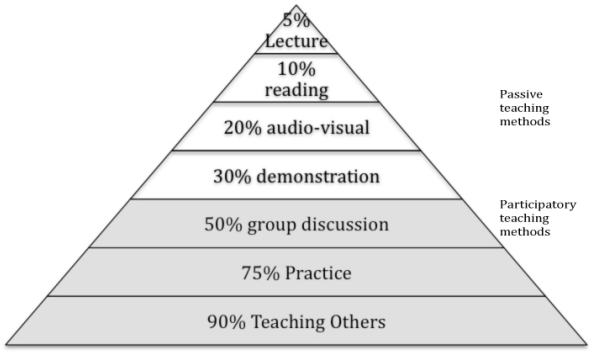

Fig. 1. Source. Attributed to National Training Laboratories, Bethel, Maine. It shows the level of learning associated with a particular activity.

This theory appears on over 1,200 web-sites according to one search engine[1] , and is present in many textbooks on teaching [11]. The theory is attributed always to National Training Laboratories, Bethel, Maine. Unfortunately, according to a recent publication, even this institution is not aware of its original source [12]. It is plausible that these pyramidal references are variations of Dale's "Cone of Experience" [13], which in itself, was not based on research. The Cone of Experience "is essentially a visual metaphor for the idea that learning activities can be placed in broad categories based on the extent to which they convey the concrete referents of real-life experiences" [14]. In Biggs and Tag [11] is suggested that this may be connected with the memory systems described by Tulving [15]. These memory systems are made up of a number of interrelated systems; procedural, episodic and semantic memory systems were identified by Tulving and, in Biggs and Tang is suggested that the way the student learn and retain information might be connected -for example- with the episodic memory if the student was performing an activity when he/she was learning new information. Therefore it is most likely that the student remember what he/she was doing when specific information was learned. This will constitute the main motivation for designing the learning activity explained later in this text.

This study has its foundation in the fact that a balanced teaching style will ensure students are taught in the way they prefer [16], [17], [18]. Lets assume that student ways of learning are uniform. If this were correct, a single method of teaching and a single type of assessment (for example exams) would be enough to evaluate the outcomes in student learning. However, previous studies have demonstrated that this approach is not widely effective [19]. For example, in engineering one student might be comfortable with abstract theories and mathematical models while others might be more open to concrete and more realistic (real-world) material. Assuming uniform student learning styles might become too uncomfortable for some students, forcing them to stretch and develop skills in areas that they might be prone to avoid if given the chance.

There is wide support [20] that suggests the most elements of active learning foster some important learning outcomes [21]. Studies suggest that student-centred learning develops more positive student attitudes, fosters a deeper approach to learning and helps students retain knowledge longer than traditional instruction [11]. This could well be related with the two bottom steps of the pyramid in Figure 1.

This has motivated, over the past years, considerable attention in alternative methods of teaching in engineering, such as active learning [10], problem-based learning (PBL), cooperative and collaborative learning [22]. On the simplest way, introducing an activity in the traditional classroom promotes active learning. For example, Ruhl et. al [8] showed significant results of adopting a pause periodically having students clarify their notes with a partner. Further evidence of this approach was presented by Di Vesta [23]. This is just an example of how introducing a variation in the traditional classroom improves students learning. But introducing an activity may fail to capture some component of learning, if is not aligned with the intended learning outcomes [24].

The overall aim of this study is to bring new insights to support the affirmation that some interactive methods are more beneficial to the student-learning outcomes than others.

II. Methodology

Up to this point, I have introduced that students learning styles are different, that traditional passive instruction is not the most effective way to achieve

[1]Google

intended learning outcomes, that information retention might be linked to the way that students acquire that information (Figure 1) and this could linked with Tulving memory systems [15]. I have used previous research and literature to

- Introduce a teaching variation in my traditional teaching style that creates a student-centred learning environment. This variation could be categorised as active learning.
- Design a TLA activity in a way that aligns with my intended learning outcomes. Moreover, uses research in cognitive science to support the actions in the TLA.
- Foster critical thinking about engineering problems.
- Guide student's learning throughout continuous individual feedback.

Using various instruments for data collection and by means of a thorough analysis I present evidence of the effectiveness of this research project which aims to improve teaching practices, with the ultimate goal of enhancing students learning.

A. Participants and settings

Data was collected over a period of one semester in a 4th year engineering degree. There were 21 students in total and the research was conducted over a period of six weeks followed by data analysis and evaluation period.

The class was divided in six different groups of students, and the content similarly portioned in six topics. Each group was asked to prepare and deliver (in class) material covering a specific topic in Aerospace Avionics engineering. The students were required to address specific aerospace content, to undertake research on the topic, and to deliver that content to the rest of the class. After each class data was gathered to assess learning outcomes of both, the students actively (delivering the content) and passively (listening the presentations) involved in the TLA. The method for evaluating students' level of understanding was by providing them with questionnaires which required the application of critical-thinking skills and prior knowledge to particular problems associated with the presented material. Timely feedback (from lecturer to student) was a considerable component in this activity and students received individual feedback after each learning activity [9]. Other instruments were used to supplement and gather additional data.

TABLE I
CORRESPONDENCE BETWEEN GROUPS AND THEIR ASSIGNED TLAS

Activity	***Topics***	***Group (Students)***
Questionnaire 1	General knowledge	All (1-21)
TLA1	Structure subsystem	Group 1 (1-3)
TLA2	Power subsystem	Group 2 (4-7)
TLA3	Thermal subsystem	Group 3 (8-12)
TLA4	Communication subsystem	Group 4 (13-15)
TLA5	Propulsion subsystem	Group 5 (16-18)
TLA6	Attitude subsystem	Group 6 (19-21)

There are a total of six TLAs directed at six groups of students. Each TLA aims to cover a particular topic about satellite subsystems and was assigned to a particular group. Data corresponding to the six weeks of the implementation of this research is shown in Table 1.

B. Instruments

For the purposes of data collection, three main instruments were used such as questionnaires, one-minute papers and interviews.

1) Questionaires: Data from questionnaires was collected on a weekly basis. Each week after the teaching activity a questionnaire (related with the topic in turn) was handed out to the students. Each TLA consists of pre-class research (performed by the target group), a presentation on a topic (delivered by the same group) and a questionnaire on the topic (handed out to the whole class). Individual questions in the questionnaire are weighted 0, 0.5, 1, and each questionnaire can be scored up to 3. The procedure for data collection using this instruments was as follows:

- Questionnaire 1 (pre-activity data collection). This instrument was delivered prior to the commencement of this study. This questionnaire represents an initial data collection for posterior comparisons. It concerns with general topics about the content to be used in this research.
- Questionnaires 2-7. After each session, another questionnaire with 2-3 questions about the topic

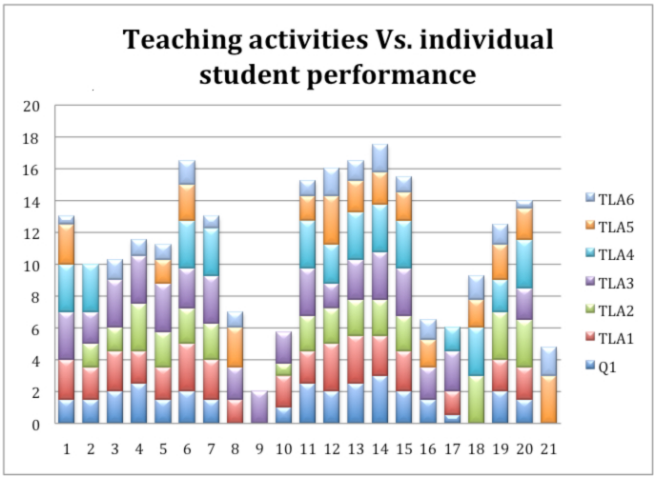

Fig. 2. Outcomes of the implementation. Six TLAs are shown and the scores of each TLA is weighted 1 to 3.

in turn was given to students. Questionnaires are scored on a scale of 1 (unsatisfactory answer) to 3 (satisfactory answer). Post-class individual feedback was given to each student. In that way, they can use this feedback for the tutorials and final exam.

2) One minute papers: The purpose of minute papers was to gather qualitative information on the topics from the student perspective. Views on the level of engagement in the activities, satisfaction and difficulties can be promptly identified helping in creating a positive learning atmosphere. In this study the minute paper was applied at the end, after all activities were concluded. Outcomes of this tool are analised in section III-B.

3) Interviews: Interviews were completed at the end of the semester. The aim of the interviews was to identify key aspects on how students felt about the TLAs, usefulness of the learning activity and learning outcomes (from the student perspective). A population of three students from different groups was used. Outcomes of this tool are presented in section III-C.

III. Analysis and Results

The primary motivation of this study was to explore and gain more insights about the relationship between active learning and learning outcomes in an engineering classroom. The challenge often resides in the proper election of active learning modality and mapping of this to the subject graduate capabilities and therefore student learning outcomes. Active learning in this study intended to shift the role of the lecturer to the each student, involving him or her in the delivery and pre-class research of certain topics. I present next the main findings of this study.

A. Data from questionnaires

Figure 2 shows the overall performance of students against teaching activities. Students are numbered from 1 to 21 (horizontal axis). Each TLA is encoded in different color and weighted 1 to 3. Preliminary data analysis (from Figure 2) suggests no direct qualitative relationship, group-TLA. Three main groups ({1-7}, {11-15}, {18-20}) could be highlighted from Figure 2. These groups have performed well on average, in most TLAs. Minute paper. As a preliminary hypothesis of this research project, I expected that groups associated with a specific TLA would perform better than other groups. Despite the pedagogical procedure and efforts to collect data in a consistent and evenly manner, this outcome is not evident. While I found consistency with my initial hypothesis in some TLAs, in others, factor such as student self-motivation and GPA distribution among groups could have had an impact on the performance obtained. Figure 3 highlights in particular groups 2, 3 and 4 as high achievers.

B. One minute papers

In general, this survey revealed a few interesting points. From a total of 17 responses out 21 (approx. 80%):

- Students found the activity TLA6 difficult (11%). This can be attributed to the fact that when comparing with the rest of topics, TLA6 was more technical and longer than others. This activity deserves attention in order to equalize the level of difficulty of all TLAs.
- Students enjoyed the TLAs in general. To the question What did you find most interesting?, some of the responses were:

I *"presentations forming part of lectures. It makes the topics more interesting."*

II *"So far, the assignments and presentations."*

III *"The presentations. Seeing real-world applications of the subsystems and concepts being presented."*

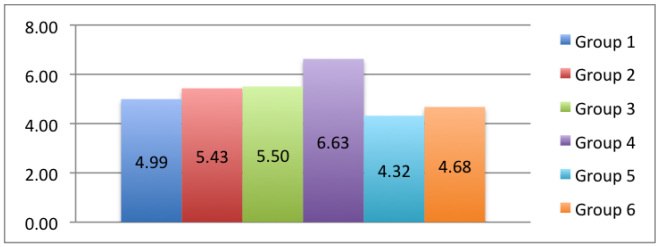

Fig. 3. GPA distribution among groups,

IV *"Feedback from tutorials. Interactive presentations."*

- Students found the feedback given after each TLA useful/interesting.
- There were difficulties with some topics. I identified the topics where students expressed their concerns.

Supporting the initial findings from the minute papers, is the data obtained from the university wide teaching evaluation survey. This survey with a 36.8% of response rate, were very positive for the subject showing an increasing trend towards the maximum numerical value of 5. While the content of the subject has remained approximately similar during the last three years (prior to the implementation of this study), the teaching style/delivery has changed significantly. Timely individual feedback on questionnaires (usually same day), increased interactivity in class, quick availability of assessment results (usually no later than 2 days after the assessment) are part of the new practices introduced during this research project, and it is believed that these represent a major contribution to the students satisfaction. However, while this instrument is the university recognized tool for teaching evaluation, studies have revealed that this type of teaching assessment may not reflect the real outcomes of teaching [25], [26]. Therefore from this instrument, only qualitative conclusions can be drawn about the effectiveness of this project in the ILOs.

C. Interviews

From the interviews, I identified key aspects -from the students' perspectives- of the TLA. For example, did the student find the learning activity useful and what was the learning outcome?. From this instrument, I identified that students remember the topic from their own presentations better than those presented by others. I believe that the purpose of the activity -in terms of ILOs- was reached for the presenting student(s) but failed to address the remaining students. This issue could be addressed by designing two different TLAs. One to address the presenting group of students and another to the rest of the class, in the same session. In this way everyone should perform a pre-class reading and research about the same topic, but only the one group is required to present it.

IV. Conclusion

The major finding of this study is the acknowledgement that my particular teaching and learning activity was well perceived by the class, and therefore successful in achieving partially student learning outcomes. This modality of active learning in which the student adopts lectures role during certain stages of the semester has created a positive learning environment during the implementation of this study.

After analyzing the results from the different data collection instruments, I can conclude that introducing interactivity [13], [23], [18] in class and shifting the focus to a student-centred [11] environment bring benefits to student's learning. In introducing these new approaches in class for the first time in the teaching practice, I can reflect about the following improvements and recommendations:

Students' self-motivation is an important factor in developing teaching activities. How do we equalize the learning amongst students when individual motivations are different? If a considerable number of students are performing well in all activities, then the outcome should be to improve the learning outcome of those students who have not performed well so far (i.e. equalize the overall learning outcome of the class). We could address this by letting students choose a topic that is of interest for them. But additionally, moving to a more active method of teaching will ensure that differences (engagement, learning, etc) between Robert/Susan-like students are minimized (see [11] page 10, Figure 1.1).

Not surprising is the fact that students with high GPAs consistently performed well in all activities. Consistent with the results obtained, Group 4 had the highest GPA on average of all groups. Groups 5 and 6 have the lowest GPA of all groups. This

could explain the fact that they did score lowest (on average) of all groups in the TLAs (Avg TLA of 4.81 and 3.72 for groups 6 and 5, respectively). For groups 1,2,3,4 we had an Avg TLA of 5.1, 6.1, 5.3, 7.3, respectively. We can observe group 4 scoring highest among the groups.

In light of the results of this study, instructors that do still support traditional, passive and teacher-centred methods of teaching & learning might be interested to review the potential benefits of active learning in their practices.

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