Assessing the Active Learning in Engineering Education Based on BOPPPS Model

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Abstract

This evidence-based paper examines the forms of student engagement in learning as is measured based on BOPPPS model. Various approaches have been used to estimate engineering education quality. Student engagement is generally considered as a better predictor of learning and personal development. The premise is deceptively simple, perhaps self-evident: The more students study or practice a subject, the more they tend to learn about it (Carini and Kuh,2006). To adopt the active learning in engineering education process, it is essential to follow the initiative and directional principles and combine with the advent of technology enhanced learning. The main proposal of this paper is to grasp the connotation and construction of the active learning with the adoption of new information technology and establish framework in application.

This paper studies three engineering courses and compares the student responses in traditional and active learning based on BOPPPS framework. (BOPPPS is the acronym of bridge-in, objective, pre-assessment, participatory learning, post-assessment and summary. In the later passage, the author uses BOPPPS instead.) These courses will be referred to as "traditional", "general active" and "BOPPPS active." By Using Kruskal-Wallis test, this study conducts quantitative analysis to determine whether there were statistically significant differences between student responses in the three courses. Post-hoc (Steel-Dwass test) is used to find which courses are significantly different from each other in statistics. Quantitative analysis on data was performed in software R version 3.4.4. Each survey item was preliminarily achieved by utilizing products of SunVote Audience Response System, which was conducted in National University of Defense Technology. This paper also develops the framework of assessment taking the following four areas into consideration: analysis; design; evaluation; implementation. At last, the prospect for the future development is put forward. In the future work, we will focus our work on two research questions. How could we further build mature model and useful information technology? How could we constantly enrich the content and methods of active learning?

Introduction

Active learning has received considerable attention in engineering education over the past several years. Active learning methods have proven to be an effective way to increase engineering self-efficacy (Carini R M,2006), academic performance(Freeman,2014), feelings of responsibility to complete future tasks(Daniel,2016), and recently retention in science, technology, engineering and math (STEM)(Elgin,2016). Even authors in the cognitive science discipline suggest that classrooms with an active learning approach can increase student motivation, knowledge retention, and content transferability (Michael, 2006; Norman and Schmidt, 1992; Vosniadou, Loannides, Dimitrakopoulous, & Papademetriou, 2001). The core elements of active learning are student's activity and engagement in the learning process (Michael Prince,2004). In short, active learning requires students to do meaningful learning activities and think about what they are doing(Bonwell,1991). Though there are already large quantities of research on active learning, the question as to where active learning headed is still lying on the way. Navigating engineering education requires an understanding of the current state and the future direction of active teaching and learning. Adding to the confusion, engineering faculty do not always understand how the common forms of active learning differ from each other (Prince 2004).

To adapt to the active learning in engineering education process, it is essential to follow the initiative and directional principles, and combine with the advent of technology in enhanced learning. This evidence-based paper examines the forms of student engagement in learning as are measured based on BOPPPS model, which is widely used in Canada in the process of training on teaching skills. The purpose of this paper is to deploy better and more effective instructional strategies in the engineering class, addressing that active learning practices as a viable alternative to the traditional (low-interaction lecture-based) environment. The main proposal of this paper is to grasp the connotation and construction of active learning with new information technology, and establish an application framework. The main innovations have been carried out as follows: theoretical roots of BOPPPS, research support of active learning, current practices of information technology, and suggestions for redesigning classes. We're trying to solve a number of relevant problems, including: What are the key components of successful deployment of active learning based on BOPPPS model? How to expand participatory teaching methods to achieve interaction with students that is necessary for the realization of the engineering education objection? What plans and resources need to be mobilized to institutionalize pedagogies of engagement including active learning, at the department or college level?

Literature Review/Background

Before discussing active learning, our efforts have been devoted to distinguishing the different types of active learning most frequently discussed in the engineering literature.

Active learning

The term "active reading" has been defined variously according to different researchers of the field. The following are some of the main definitions: All learning is some sense active, but active learning refers to "the level of engagement by the student in the instructional process" (Fern et al 1995). Active Learning is "an effort to make learning authentic" (Carson 1995). Active Learning puts the responsibility of organizing what is to be learned in the hands of the learners themselves, and ideally lends itself to a more diverse range of learning styles (Dodge 1996). Active Learning attempts to model the methods and mindsets which are at the heart of scientific inquiry, and to provide opportunities for students to connect abstract ideas to their real world applications and acquire useful skills, and in so doing gain knowledge that persists beyond the course experience in which it was acquired (Allen & Tanner 2003). Prince (2004) defined "active learning as any instructional method other than lecture that engages students in learning". Prince's definition of active learning emphasizes the instructor's role in the classroom.

Active Learning refers to techniques where students get involved more actively in the process of learning than just simply listen to a lecture. Students are doing something including discovering, processing, and applying information (McKinney 2007). Active Learning is comprised of a student-centered environment which raises student's motivational level to stimulate thinking and go beyond facts and details (Brody 2009). With respect to active learning, there are many interrelated vocabulary, e.g. collaborative learning, cooperative learning, problem-based learning (PBL). Collaborative learning and peer tutoring in the university environment can positively influence students to maintain a constant motivation and affection towards their study (Concetta 2018). Collaborative learning and cooperative learning are different, for they have distinct historical developments and different philosophical roots (Bruffee,1995). The most common model of cooperative learning found in the engineering literature is that of the book: 'Active Learning: Cooperation in the College Classroom' (David W. Johnson, Roger T. Johnson, Karl A. Smith,1998). This model incorporates five specific tenets, which are individual accountability, mutual interdependence, face to-face promote interaction, appropriate practice of interpersonal skills, and regular self-assessment of team functioning. The core element of learning is a focus on cooperative incentives rather than competition. Problem-based learning (PBL) is an instructional method where relevant problems are introduced at the beginning of the instruction cycle and used to provide the context and motivation for the learning that follows. PBL typically involves significant amounts of self-directed learning on the part of the students (prince 2004).

Pedagogy and Technology

The theoretical foundations of different active learning pedagogies are difficult to flesh out as they are often used interchangeably and without clear definition (Savery, 2006). Several research studies have covered effective pedagogical strategies for active learning, while other researchers seek to testify whether classification of active learning pedagogies would be useful in comparing pedagogies, in theory and practice. There are five distinct active learning pedagogies: problem-based; discovery-based; inquiry-based; project-based; and case-based learning (Kelsey Hood Cattaneo 2017). The six elements of constructivism are depicted as lack of emphasis on assessment, which contain learner-centeredness, focus on process and content, use of interdisciplinary lessons, use of collaborative lessons, focus on student reflection, importance of intrinsic motivation).(Jonassen ,1991). However, any learning pedagogy has its limitations. For example, Problem-based learning(PBL) has been criticized as a curriculum that is often poorly designed and implemented, and a pedagogy that lacks objective-aligned assessment methods (Boud & Feletti, 1997). Other research found, without proper scaffolding, consistent feedback, or context, students in PBL classrooms have shown less progress than students in traditional classrooms (Savery, 2006,Norman & Schmidt, 1992;). Most supporters of discovery-based learning acknowledge the main critiques of the pedagogy as fellow: a lack of teacher support, teacher guidance, content focus or learning objectives. The need for teacher guidance and curricular and process bounds, especially for naïve learners (Kelsey Hood Cattaneo,2017). It is recommended that pure discovery learning could be reserved for expert knowledge explorers with extensive experience and expertise. (Alfieri, Brooks & Aldrich, 2011, p. 2). Owens, Hester, and Teale (2002) suggest that inquiry-based learning (IBL) classrooms are driven by questions that focus and frame inquiries. It is often associated with the problem-based learning, and described as a method rather than pedagogy. Bauchi and Bell (2008) describe four different inquiry stages, which are confirmation, structured, guided and open. Students from novice to expert levels could accomplish problem solving skills in corresponding stage. It's obvious that IBL's problem is similar to PBL. Project-based pedagogy has been described as one that "involves completing complex tasks that typically result in a realistic product, event, or presentation to an audience" (Barron and Darling Hammond, 2008). Some argued, after examining project-based learning in practice, that projects were often used as a tool rather than a complete theory of learning (Savery,2006). Case-based learning (CBL) is described as a pedagogy that involves exploring, diagnosing, problem-solving and repeating to reach understanding (Maudsley, 1999; Thistle Thwaite et al., 2012).

Overview of Active Learning Design models

There are dozens of pedagogic strategy models in active learning design.

◆ Problem-based learning model. Its main purpose is to develop problem-solving skills in certain subject. The outline of the model are as follows : (a) Students receive the problem; a list of objectives that students are expected to master while working on the problem; relevant reference and list of materials; important questions on concepts. (b) Students finish the project in teamwork, accomplish the learning objectives and resolve the problem together. Each project has a different node to allot. Every student has different roles in the team and an autonomous right to decide how to use the allocated time. (c) Student performance is evaluated by instructors, peers, and themselves with adoption to questionnaires, interviews, observations, and other assessment methods.

◆ Inquiry-based learning model. Its main purpose is to investigate learning and concept methodology. The outline of the model are realized in the form of a typical procedure of student activities, that is, Ask (students ask questions)—Investigate (collect information, observe and do experiment)—Create (write report ,synthesize and find out)—Discuss (confront and share ideas)—Reflect (examine results and look at questions again), which may circulates several times.

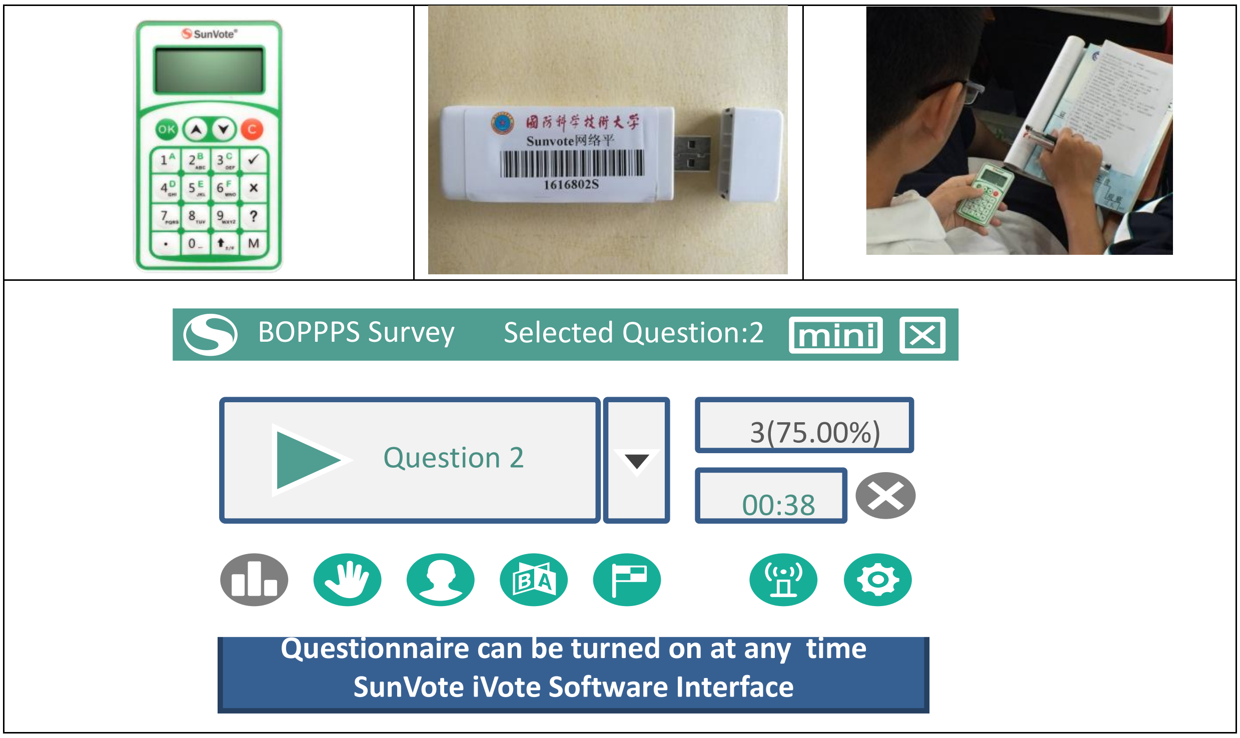
- Project-based learning model. Its main purpose is to acquire applicable knowledge in deep project manners. There are 4 phases in a typical project: (a) Starting point. Define the timelines, topic of overall course, milestones and assessment methods; identify resources, prerequisites and project-methodology. (b) Initial project-planning. Formulate objectives and questions; define knowledge pooling by team members; formulate teacher feedback; revise project specification and plan (if it is needed to return to steps (a) and (b)). (c) Project implementation. Students complete one task and milestone at a time. Make sure that students engage in regular meetings; refine definition of the project; share among team members and make sure that there is collaboration and cooperation; provide feedback and move toward completion. (d) Completion. Students have to polish the final product and prepare associated presentations; assess the whole project.

From the above analysis we can see, what is clear is that many literatures described active learning as a method (that is, a tool, kit, or package) rather than pedagogy (or expressed differently, an environment which considers both the theory and the practice of learning) (Kelsey Hood Cattaneo 2017). In every case, it is the student's interaction rather than learning as a solitary activity that is the core element of active learning. "Learning" is a complex multi-dimensional phenomenon and it is not obvious to identify learning goals. It is generally recognized that learning is composed of learning theory, learning types, learning levels, learning affect and motivation etc. Learning theories, which can be understood as looking at learning in different ways, lead to different designs of class, such as behaviorism, constructivism, social cognition, situated & shared cognition etc.

Development on BOPPPS Survey

The goal of our research project is to assess the active learning instructional practices based on BOPPPS model and to contribute to an engineering education area of research that has not been well documented. We have developed a BOPPPS survey instrument, the survey of student response to practices, to measure elite engineering students' reaction to active learning. It will collect empirical data specifically focused on student responses in traditional and active courses. This paper compares student responses between traditional and active learning engineering classrooms, and the data presented will show how effectively the BOPPPS instruction has produced. The assessment process for the BOPPPS Survey involves five different phases in this paper: item generation, environment design, emotion analysis, validity testing and piloting of our protocol. During the environment design phase, we have adopted SunVote Classroom Response System (CRS), which is a kind of system capable of providing real-time classroom feedback. This stable wireless transmission system is short and portable, thus is specifically suitable for active learning assessment. The keypad, radio transmitter and drive software can be seen in Figures 1. This paper has evaluated the impact of using CRS on student-involvement from perspectives of both the instructor and students. Student participation with the use of CRS is measured directly along with overall course satisfaction. The application of classroom response systems has been shown as an effective method of enhancing learning in larger classroom settings (McLoughlin, 2008). During the emotion analysis phase, the Academic Emotions Questionnaire (AEQ) was used as a tool to assess students' emotions over time in academic settings (Reinhard Pekrun, et, 2002). Many researches has indicated that it is necessary to create an open and welcoming environment where the learners feel comfortable enough to be motivated to offer feedback. That is why we take the change of the student's mood as an important research content. We also conducted cognitive interviews with students and instructors to assess the accuracy of the responses to our emotion items. During the validation phase, we have developed new protocol to qualitatively explore our initial BOPPPS model to attest whether the survey met a criterion in efficiency and accuracy. We have followed some cognitivist design principles to assess the effect. For example, Gagne's 9 steps of instruction. Early qualitative results from the observation protocol indicated that they are variations in student engagement levels with the type of active learning implemented in the classroom (Shekhar,2015)

Figure 1: SunVote Classroom Response System and its iVote Software Interface

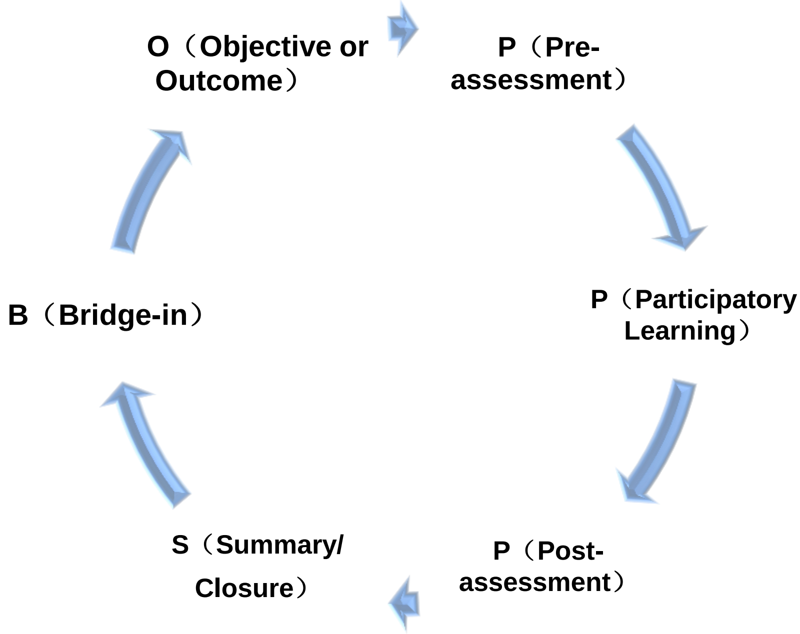


After the design of BOPPPS validation process, we piloted our assessment during academic year 2015/16. Our assessment instrument asked students and instructors to describe several phases of the BOPPPS they experienced (to allow for documentation of the nature of the class overall) as well as their reactions to episodes of active learning instruction. The survey was administered four times throughout the courses which were held at National University of Defense Technology. The goal of the course is to improve the leadership in diverse dimensions and to discuss how to help learners benefit from different perspectives and opportunities. The course, an intensive 28 to 30 hours event, is a high-end interactive learning activity. For the assessment, the research team chose both active learning based on BOPPPS and traditional instruction courses (i.e., mainly instructor-focused practices without feedback). The coverage of courses with both traditional and nontraditional instructional practices was useful for us conducting cause and effect analysis and finding confirmatory factor.

Population, Instrument model, and Quantitative Methods

This practical pilot was performed at a large elite university during academic year 2015/16. Three courses were sampled: an engineering practice of leadership course (n=38), a S&T innovation epistemology and methodology course (n=46) and a major engineering practice and thinking course (n=39). The n-values represented the total student's number who finished the survey. For the assessment of the paper, these three courses will be ranked as "traditional", "general active" and "BOPPPS active". The leadership course served as "traditional" courses, students are not as involved in lectures as they could be, and courses status feedback from instructors to students by post-class or some weeks later. The methodology course was "general active", it was designed on the basis of active learning strategies and including a high amount of problem solving feedback. The thinking course also served as one of the active courses, and this course was designed based on BOPPPS model. BOPPPS is the theoretical foundation of Instructional Skills Workshop (ISW). ISW Teaching Methodology, originated in Canada, has been widely valued in North America and has now extended its influence over the world. BOPPPS is a closed-loop teaching process model that emphasizes student participation and feedback. It is a collaboration between facilitators and participants that is grounded in active, experiential learning, and based on principles of learning-centered instruction (Janice Johnson,2006). The overall cycle of "BOPPPS active" is provided in Figure 2.

Figure 2: The overall cycle of "BOPPPS active"



For the remainder of the paper, these courses will be referred to as "traditional", "general active" and "BOPPPS active." Preliminary skills training of the active courses verified that these courses fit BOPPPS elements, and the course instructors also confirmed these elements reflecting their type of teaching. The 123 engineers participated in three engineer talent courses come from industry and academia. Many of them led groups of engineers, business teams, academic teams, and others managed multiple projects within their professional field. In terms of the education background and education experience of the participants, most of them are highly educated or have the experience of studying abroad. The majority has doctor's degree. The three courses students(n) sampled are summarized in Table 1.

Table 1. Summary of Engineering courses and Students Sampled

Course Title	Key Identifier	n	Age range				education background		
			<40	41~ 45	46~ 50	>51	Bachelor	Master	Ph.D
Engineering Practice of Leadership	"traditional"	38	7	16	12	3	2	11	25
S&T Innovation Epistemology and Methodology	"general active"	46	9	18	13	4	3	13	30
Major Engineering Practice and Thinking	"BOPPPS active"	39	8	17	12	2	3	10	26

Based on the analysis of the class, it is showed that students are in similar age and possess similar education background. That is, they have similar foundation, which ensures a following evaluation and consistent statistics to be scientific. With the aim to realize our evaluation on the same basis, we have worked out a questionnaire

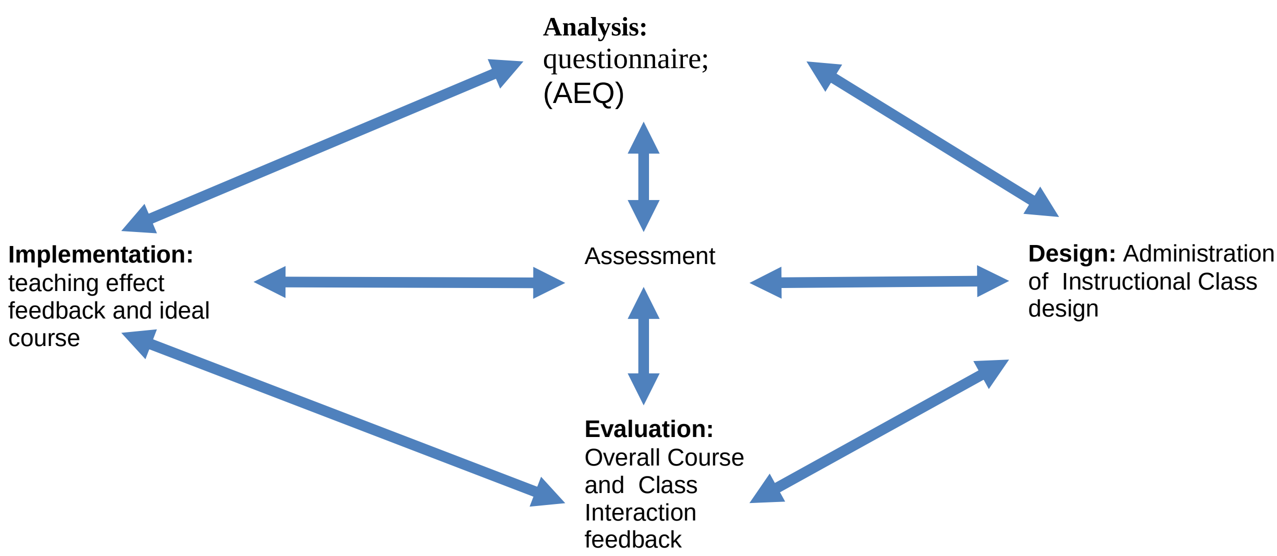
(Table 2) to demonstrate students from three different classes share the same degree of understanding towards active learning.

Table 2. Questionnaire of students

Question	Items	Label Code(for anaysis)
1.How many active learning courses have you ever been instructed in your Engineering Education？	Every engineering education course	5
	Almost every Engineering education course	4
	About half of my engineering education course	3
	A few of my engineering education course	2
	Almost None	1

According of the instructional methodology, we have developed an evaluation model, with the intent being that feedback would inform ongoing implementation. Three separate surveys were carried out for students and instructors that are labeled as "traditional","general active" and "BOPPPS active. "All these surveys adopted Likert type questions to explorer analysis. Questions were developed based on consideration for four areas (1) analysis; (2) design; (3) evaluation; (4) implementation. The second step focused on student's emotion to course design, which compared students and instructors responses in traditional and active learning classrooms. The data presented is drawn from a subset of Academic Emotions Questionnaire (AEQ) data collected to pilot our assessment survey(See Appendix 1). The third step focused on how the students perceived the administration of in-class activities by the instructor (See Appendix 2), and the fourth step directly asked students to measure Overall Course and Class Interaction feedback within the course (See Appendix 3), and the last step asked students to report the whole procedure of BOPPPS and indicate which in-class activities would comprise their ideal course (See Appendix 4). The Framework of assessment is listed in Figure 3.

Figure3. The Framework of assessment



Results of the Assessment

In order to analyze the data in the three different courses, we used a Kruskal-Wallis test to determine if there were statistically significant differences in these courses. Answers were predominately coded on a five point

Likert type scale from 1 to 5 for most of the survey areas. Some missing or obvious wrong answers were coded as “0” and removed from statistical analysis. Quantitative data analysis was performed in software R version 3.4.4.

the sample mean($\bar{X}$) contains the average of the observations for each variable, and is written as

$$\bar{\mathbf{x}} = \frac{1}{N}\sum_{i=1}^{N}\mathbf{x}_i = \begin{bmatrix} \bar{x}_1 \\ \vdots \\ \bar{x}_j \\ \vdots \\ \bar{x}_K \end{bmatrix}$$

The standard deviation (SD, also represented by σ) is a measure that is used to quantify the amount of variation or dispersion of a set of data values.

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}, \text{ where } \mu = \frac{1}{N}\sum_{i=1}^{N} x_i.$$

The p-value or probability value is the probability for a given statistical model. A chi-squared(also represented by χ2), is statistical hypothesis test where the sampling distribution of the test statistic is a chi-squared distribution when the null hypothesis is true. Degrees of freedom (df) is the number of parameters of the system that may vary independently. In this study, post hoc analysis (from Latin post hoc, "after this") consists of analyses that were not specified before seeing the data. And the difference appears in all courses when compared pairwise (Post-hoc Steel-Dwass test; $p < 0.001$).

Primary Analysis on Active Learning from Students

To ensure the research objects are at the same level, we implemented an analysis on students active learning components before our research (Table 2). There was no statistically significant difference between the three courses using the Kruskal-Wallis test (P-Value = 0.1323, χ2 = 3.18, df = 2). In these three groups of students, $\bar{X}$≈3, σ≈1., which showed that students has almost the same active learning in “about half of his engineering education courses.” So, students in all three courses had roughly the same amount of active learning experiences, which ensured the scientific development of the research.

Academic Emotions Questionnaire (AEQ) Analysis

To improve the effect of active learning, it is necessary to create an open and welcoming environment where the learners feel comfortable enough to be motivated to actively learning. That is why we take the student's emotion as an important assessment content (Table 3). Table 3and Table 4 provided statistically AEQ items for students’ responses towards traditional and active learning activities. Based on our exploratory evidence, Table 3 provided the items that was not statistically different from other two courses (P>0.05). Although there are no post-hoc identifiers found to link these items to a course, we categorized the domain of AEQ as Positive or Negative by its average means (x). The items are listed in Table 3. Table 4 listed the statistically significant AEQ items.

Table 3: Non-Statistically significant AEQ items

Academic Emotions Questionnaire (AEQ) data	BOPPPS active		general active		traditional		Kruskal-Wallis test			Post-hoc Steel-Dwass test
	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	P	χ2	df	
I enjoyed the class and its learning	4.47	0.97	3.88	0.93	3.89	1.00	0.411	1.785	2	Positive

activity.										
I felt Boredom towards the instructor/class.	1.23	0.72	1.45	1.36	1.26	0.73	0.357	2.054	2	Negative
I pretended but did not actually enjoy the class.	2.11	0.92	2.32	0.94	2.29	0.73	0.154	3.765	2	Negative
I felt shame to answer the question.	1.75	0.85	2.14	1.05	2.71	0.86	0.121	18.002	2	Negative
I felt sadness for the course.	2.01	0.73	1.46	1.35	1.26	0.73	0.231	17.03	2	Negative
I distracted my peers during the class activity.	2.12	0.98	1.99	2.02	1.87	0.34	0.214	16.03	2	Negative
I felt the time used in class was beneficial.	4.23	0.71	3.90	0.92	4.09	0.34	0.056	5.775	2	Positive
I am proud of being attend this class.	4.04	0.85	3.88	1.04	4.10	0.45	0.604	1.009	2	Positive
I felt deep disappointment toward the design of class.	1.40	0.72	1.46	1.36	1.24	0.73	0.358	2.005	2	Negative

Table 4: Statistically significant AEQ items

Academic Emotions Questionnaire (AEQ) data	BOPPPS active		general active		traditional		Kruskal-Wallis test			Post-hoc(Steel-Dwass test)
	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	P-Value	χ2	df	
Because of the Build-in introduction, I was full of anxiety about this course.	4.32	0.93	4.11	0.86	3.98	0.93	0.000	48.002	2	BOPPPS
I saw the value in the activity.	3.54	1.45	3.21	0.89	3.12	0.45	0.000	23.32	2	General
I am full of hope for the course.	3.67	0.73	3.31	0.89	3.71	1.04	0.001	12.232	2	Traditional
I focused on active learning specially when the instructor asked.	3.98	0.34	3.69	0.98	3.32	0.04	0.000	32.001	2	BOPPPS
I felt joy about success when talking with classmates about the topics.	3.01	0.98	3.34	0.80	4.00	1.00	0.000	12.220	2	General
I felt the effort it took to do in the active learning was worthwhile and I was satisfied with it.	4.01	0.54	3.98	0.45	3.76	0.32	0.000	29.002	2	BOPPPS

Overall, AEQ items appeared that students always responded positively to active class activities, as $\bar{x}$ scores are higher for positive type items and lower for negative type items. Table 4 presents six items for which AEQ items were statistically significant different (Kruskal-Wallis test) for the three course types and gives an identifier (Post-hoc Steel-Dwass test) to show where the difference took place. For example, the activity "Because of the Build-in introduction, I was full of anxiety about this course", which is a significant different in statistics from both the other two courses ($p<0.001$, $\chi2=48.002$, df=2) and the BOPPPS active's difference appearing in other two courses when compared pairwise (Post-hoc Steel-Dwass test). The other two activities, "I focused on active learning especially when the instructor asked" ($p<0.001$, $\chi2=32.001$, df=2), "I felt the effort it took to do in the active learning was worthwhile and I was satisfied with it." ($p<0.001$, $\chi2=29.002$, df=2) is also showed pairwise differences, so it is very useful for our next analysis. Three of other activities are related to either "general active", or "traditional", these activities verified that our research survey's correct indication towards the characterizations of the traditional and active learning courses.

Some AEQ items are not statistically significant in terms of the distribution of scores between all three courses, such as, "I felt Boredom towards the instructor/class.", "I felt deep disappointment toward the design of class.", "I felt shame to answer the question." Although we think these items may take place in the traditional course, but these three courses ($P>0.05$) which means that these items were not statistically significantly different from both the other two courses. It showed that in these courses, all students have the positive attitude towards the engineering education, which is interesting for us to take more analysis.

Administration of Instructional Class Design Analysis.

The core class structure is the participatory interaction between teachers and students. In order to determine how class design activities were administered for each course, students were asked to rate the administration of the Instructional Class Design (see Appendix 2). There were some statistically significantly different items, and these items are listed in the Table 5. Three items have showed statistically significant pairwise difference, "Having and using a useful, practical active learning implementation plan ($p<0.001$, $\chi2=18.002$,df=2).","Work closely with peers to improve mutual understanding of leadership($p<0.001$, $\chi2=9.652$,df=2).","Practice various leadership strategies and techniques."($p<0.001$, $\chi2=48.002$,df=2). But the other five items have not showed significant pairwise differences, these items are listed in the Table 6.

Table5： Instructional Class activities Statistically Significant Items（3 of 8 ）

Administration of Instructional Class items	BOPPPS active		general active		traditional		Kruskal-Wallis test			Post-hoc(Steel-Dwass test)
	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	P-Value	χ2	df	
Work closely with peers to improve mutual understanding of leadership .	3.57	0.85	3.69	0.93	4.65	0.55	0.000	9.652	2	BOPPPS active
Practice various leadership strategies and techniques.	4.07	0.93	3.39	0.65	3.65	0.75	0.000	48.002	2	BOPPPS active
Having and using a useful, practical active learning implementation plan.	4.75	0.85	4.14	1.05	3.71	0.86	0.000	18.002	2	General active

Table 6： Instructional Class activities not Statistically Significant Items（5 of 8 ）

Administration of Instructional Class items	BOPPPS active		general active		traditional		Kruskal-Wallis test		
	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	P-Value	χ2	df
Raise awareness of participatory learning concepts.	4.42	0.95	3.78	1.06	3.57	0.84	0.054	18.453	2
Discuss with a range of different professional backgrounds and disciplines.	4.48	0.96	3.99	1.02	3.23	0.65	0.122	11.740	2
Consideration of engineering needs arising from future technical development.	4.67	0.43	4.38	0.88	4.23	0.95	0.002	11.232	2
Use common scientific and technical resources and accept constructive feedback.	3.67	0.94	3.56	0.23	3.83	0.34	0.003	9.653	2
Use basic technology to test learning.	3.22	0.45	3.43	1.02	3.02	0.55	0.043	21.659	2

Evaluation of the Overall Course Design.

Overall, all students highly evaluated both the course and instructor, but there are some statistically differences between these three courses (see Appendix 3) . Table 7 listed the results of the three survey items. “BOPPPS active” class has reached the highest score for it emphasizes student-centered teaching, and student's active participation process.

Table 7： Evaluation of the Overall Course Design

Administration of Instructional Class items	BOPPPS active		general active		traditional		Kruskal-Wallis test		
	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	P-Value	χ2	df
Overall, this was an excellent active course.	4.21	0.68	4.01	0.72	3.97	0.56	0.031	6.678	2
Overall, you recognized the importance of establishing a positive learning environment.	4.35	0.56	4.21	0.80	4.11	0.43	0.010	8.342	2
Active Learning Positively changed student-student, student-instructor interaction.	4.54	0.91	4.32	0.45	3.68	0.23	0.021	4.322	2

Implementation of procedure of BOPPPS and which would comprise their ideal course.

In order to assess the active learning based on BOPPPS model perfectly, we have designed the FAQs to evaluate the whole procedure of BOPPPS (see Appendix 4). For our analysis, we let the students indicate how often you or your instructor did in this course and how often you would like to do it each in your ideal course. Table 8 provides statistically significant different items (Kruskal-Wallis test) for the three course types and gives an identifier (Post-hoc Steel-Dwass test) for students' response to BOPPPS activities. It is very useful to see that Table 8 provided showed that the general trend of positive reactions to BOPPPS in-class activities items. The Students were also asked to describe their ideal course in their own points (Table 9). Only three items demonstrated statistically significant difference ("Brainstorm different possible solutions to Engineering leadership training," "In the "Pre-Assessment" section, Allow learners to express their needs for review or clarification" and "In summary, Solve problems that have more than one correct answer."), And this item showed pairwise differences (Post-hoc Steel-Dwass test). Thus, this item is very helpful for our current analysis.

Table 8：Implementation of procedure of BOPPPS Practices statistically significant different items（7 of 20）

Implementation of procedure of BOPPPS Practices	**BOPPPS active**		**general active**		**traditional**		**Kruskal-Wallis test**			**Post-hoc(Steel-Dwass test)**
	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	P-Value	$\chi 2$	df	
In the "motivational statement" or "bridge-in" section, the instructor explains the value of the lesson to the learner	4.07	0.93	3.39	0.65	3.65	0.75	0.000	48.002	2	BOPPPS active
In terms of course objectives, considering the variable needs of learners.	3.87	1.03	3.43	0.93	4.00	0.33	0.000	10.31	2	BOPPPS active
In terms of course objectives, Learning event specified for what you need to know.	4.75	0.85	4.14	1.05	3.71	0.86	0.000	18.002	2	General active
In the "Pre-Assessment" section, Reveal learners' interests and Consistent with it.	3.54	0.94	4.33	1.23	3.43	0.98	0.000	21.43	2	BOPPPS active
In terms of participatory learning, Experience the diversity of a contemporary classroom.	3.56	0.94	3.87	1.22	3.45	1.01	0.000	15.92	2	General active
In summary, Using questions and question sequences effectively during a lesson.	3.83	0.93	3.67	0.92	3.56	0.34	0.000	42.34	2	General active
In summary, Practice a variety of instructional strategies and techniques.	2.60	0.54	2.78	0.23	2.90	1.07	0.000	23.12	2	General active

Table 9:Implementation of BOPPPS Learning Practices statistically significant different in their ideal course (3 of 20)

Implementation of procedure of BOPPPS Practices items in the ideal course	**BOPPPS active**		**general active**		**traditional**		**Kruskal-Wallis test**			**Post-hoc(Steel-Dwass test)**
	$\overline{X}$	σ	$\overline{X}$	σ	$\overline{X}$	σ	P-Value	χ2	df	
In terms of course objectives, Brainstorm different possible solutions to Engineering leadership training.	3.57	0.85	3.69	0.93	4.65	0.55	0.000	9.652	2	BOPPPS active
In the "Pre-Assessment" section, Allow learners to express their needs for review or clarification.	4.07	0.93	3.39	0.65	3.65	0.75	0.000	48.002	2	BOPPPS active
In summary, Solve problems that have more than one correct answer.	4.75	0.85	4.14	1.05	3.71	0.86	0.000	18.002	2	BOPPPS active

Key Findings of the Results and Discussion

The BOPPPS survey model has successfully been assessed in "BOPPPS active", "general active", and "traditional" courses. Some key elements were identified with the Kruskal-Wallis test and Post-hoc (Steel-Dwass test). In order to achieve better supplementary survey, we did individual interview on parts of students and gathered their opinions for complement.

1. It is a significant segment to draw attention to 'Build-in' and 'bridge-in' section in class , based on the traditional theory of BOPPPS.

The BOPPPS active was identified along with the Survey items, and the most typical ones were "Because of the Build-in introduction, I was full of anxious about this course.", "I focused on active learning specially when the instructor asked.", "I felt the effort it took to do in the active learning was worthwhile and I was satisfied with it.", "In the 'bridge-in' section, the instructor explains the value of the lesson to the learner.", "In terms of course objectives, considering the variable needs of learners.", "In terms of course objectives, Learning event specified for what you need to know.", "In the "Pre-Assessment" section, Reveal learners' interests and consistent with it.", "In terms of participatory learning, Experience the diversity of a contemporary classroom.", "In summary, Using questions and question sequences effectively during a lesson.", "In summary, Practice a variety of instructional strategies and techniques." These results formed a very strong support to indicate the effectiveness of the survey in distinguishing different active learning styles. We also found from these items that the most fundamental thing in implementing BOPPPS model is to highlight the effectiveness of classroom in the aspect of "bridging between students and instructors". Remember that responsibility for learning rests primarily in the learners, so the students could fully enjoy the fun brought by the in-depth participation in the classroom.

Recommendation #1: *Follow Broome classification principle of the requirements. Providing reasons for learning why this topic is important and how it may be useful in other situations; Linking lesson topic to material already studied or learners' realm of experience. Sometimes telling a story connected with the lesson topic to enhance students' learning self-Efficacy.*

2. It is necessary to construct an open and welcoming environment with equipment, so it could

improve depth of classroom feedback and level of students' participation

In the overall course data set, students responded positively to all three courses. Someone may hold the view that since the "traditional course" would not implement much active learning, why did it still receive rather positive results? According to our analysis, it may attribute to the traditional course learner being elite and their capability of responding well regardless of the action of the instructor. But these preliminary results still suggest that students do not negatively respond to or resist in-class activities as much as faculty members and instructors have originally thought. Overall, all students highly evaluated both the course and instructor, but there are some statistically differences among these three courses. Table 5 listed the results of the three survey items. "BOPPPS active" class has reached the highest score as it emphasizes student-centered teaching and student's active participation process. So in the active learning mode, feedback (verbal and non-verbal) is the key link to improving the effectiveness of active teaching. The items "in summary, practice a variety of instructional strategies and techniques", "the instructor explains the value of the lesson to the learner, in terms of course objectives, considering the variable needs of learners" also clarify that it is important to tell the students what the future engineer have to do.

Recommendation #2: *a) the in-class teaching should focus on the task, and the enhance of content depth is the key node to realize the development of the culvert in the in-class teaching; b) A variety of measures on classroom efficiency guide the students to participate in the subjective initiative of the class. To deepen the students' understanding of the core knowledge by exploring the depth of teaching content in class. For example, organizing teaching in open group discussion can actively guide students to understand and master the core knowledge from the multi-dimensional degree, and improve the mutual relationship among students.*

3. The research also suggests additional methods that could be used in active learning in engineering education.

Cultivating innovative talents is an important developing trend in engineering education, and some of the students have expressed doubts about how hard it is. In order to assess the active learning, we have designed a method which contains four steps (Analysis, Design, Evaluation, Implementation), and used a Kruskal-Wallis test and Post-hoc (Steel-Dwass test) to figure out whether there were statistically significant differences in these courses. Some student's responses and information of administered instructional practices have gained higher mean scores($\overline{X}$) than in the traditional courses, such as, "raise awareness of participatory learning concepts", "discuss with a range of different professional backgrounds and disciplines", "connect with colleagues from a range of disciplines." It is valuable to analyze these methods in further statistical research, for they are proved to be effective in practice. Although there are statistically significant differences among the three courses in other parts of the survey, these differences are not strong enough to lead to conclusions that one course is indeed much different than the two other courses in terms of student reactions, instructor strategies, or student characteristics. The paper suggests that the appropriate survey can be used in active learning courses to differentiate various types of in-class instructional practices as well as support the lack of feedback of student activities. We have also found that someone may not try to write a perfect objective on the first try. Effective training is an important precondition for well-done teaching practice. Instructors and students are required additional technical training and exposure to conduct active teaching.

Recommendation #3: *The instructors needs carefully to decide whether the lesson objective is primarily to be "performance" or "expressive." And select an action verb that best describes the kind and level of learning objective. The objective criteria are the foundation for selection of teaching media, materials, activities and technologies. Laying the foundation for the assessment of learning, ensures everyone in the course understands what is expected and what happens after the completion of the study.*

Limitations and Future work.

Although there are already some research methods existing for statistical analysis, authoritative theory and instrument are still not well-developed for active learning assessment. Similarly, there are some limitations in this paper. (1) Although similar in general, differences in terms of courses as well as students participating in the evaluation inevitably bring limitations. (2) There is limitation on sampling, including a limited number of courses, and being restricted to a certain school curriculum and students, which impacts the universality of the results. In addition, related researches are not sufficient to support the research of different types of courses/ different teaching experience levels. (3) Individual factors in student evaluation also have an impact on the objectivity of the results. Although we have analyzed the students' emotions with quite positive results and also adopted the evaluation method to make comparison from each other, evaluation results are still inevitably influenced by students’ participation, emotional status, and attitude towards active learning. The impact may even be an overestimation of the difference between courses.

In the following study, we will contribute our efforts to reducing the impact of subjective evaluation of students and promoting the development of active learning through more sophisticated models. Our research data shows that applying certain methods to test the difference between traditional learning and active learning is of great significance for improving the quality of engineering education and improving student participation. Related surveys have been able to properly distinguish the characteristics of the BOPPPS model. Although it is still insufficient to recognize other types of active learning or even traditional learning, the conduction itself is an effective exploration after all. On this basis, we plan to further improve the model (analysis, design, evaluation, and practice) and expand the number of samples. We are with a plan to target different institutions across the country to conduct analysis of various courses. Relevance and factor analysis, added with regression models, will be used to sort out the factors that affect students' active learning and they are to be implemented in combination with different learning phases.

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Appendix 1: Academic Emotions Questionnaire (AEQ) data Area

1.In this course, Which emotions do you experience when attending class, studying, and answering questions ? How often did this emotions affect your learning, academic achievement?	1.Almost never(<10% of the time)	2.Seldom(~30% of the time)	3.sometimes(~50% of the time)	4.Often(~70% of the time)	5.Very often(>90% of the time)
a. I enjoyed the class and its learning activity.	1	2	3	4	5
b. Because of the Build-in introduction, I was full of anxiety about this course.	1	2	3	4	5
c. I felt Boredom towards the instructor/class.	1	2	3	4	5
d. I pretended but did not actually enjoy the class.	1	2	3	4	5
e. I saw the value in the activity.	1	2	3	4	5
f. I felt shame to answer the question.	1	2	3	4	5
g. I am full of hope for the course.	1	2	3	4	5
h. I felt sadness for the course.	1	2	3	4	5
i. I focused on active learning specially when the instructor asked.	1	2	3	4	5
j. I distracted my peers during the class activity.	1	2	3	4	5
k. I felt the time used in class was beneficial.	1	2	3	4	5
l. I am proud of being attend this class.	1	2	3	4	5
m. I felt joy about success when talking with classmates about the topics.	1	2	3	4	5
n. I felt deep disappointment toward the design of class.	1	2	3	4	5
o. I felt the effort it took to do in the active learning was worthwhile and I was satisfied with it.	1	2	3	4	5

Appendix 2: Administration of Instructional Class Design Area.

2.In this course, when the instructor provide methodologies for class arrangement and asked you attend active class activity ?(e.g., It is grounded in active, experiential learning, and based on principles of learning-centered instruction.) How often did the instructors do the following things?	1.Almost never(<10% of the time)	2.Seldom(~30% of the time)	3.sometimes(~50% of the time)	4.Often(~70% of the time)	5.Very often(>90% of the time)
a. Work closely with peers to improve mutual understanding of leadership	1	2	3	4	5
b. Practice various leadership strategies and techniques	1	2	3	4	5
c. Raise awareness of participatory learning concepts	1	2	3	4	5
d. Discuss with a range of different professional backgrounds and disciplines	1	2	3	4	5
e. Emphasize the clear and achievable learning goal.	1	2	3	4	5
f. Having and using a useful, practical active learning implementation plan	1	2	3	4	5
g. Use common scientific and technical resources and accept constructive feedback	1	2	3	4	5
h. Use basic technology to test learning	1	2	3	4	5

Appendix 3: Overall Course and Class Interaction feedback Area

3.Please rate your level of agreement with the following items.	1.Strongly disagree	2.Disagre	3.Neutral	4.Agree	5.Strongly agree
a. Overall, this was an excellent active course.	1	2	3	4	5
b. Overall, you recognized the importance of establishing a positive learning environment.	1	2	3	4	5
c. Active Learning Positively changed student-student, student-instructor interaction.	1	2	3	4	5

Appendix 4: Activities of whole procedure of BOPPPS and which in-class activities would comprise their ideal course

4. According your understanding of active learning, Please indicate how often you or your instructor did **in this course** and how often you would like to do it each **in your ideal course**.		**1.Never**	**2.Seldom(< 3 times)**	**3.Sometimes(3-5 times)**	**4.Often(5-10times)**	**5.Very often**		**1.Much less**	**2.Slightly Less**	**3. Good**	**4.More Often**	**5.Much more**
a. In the "motivational statement" or "bridge-in" section (which is meant to gain attention and establish relevance for the lesson), the instructor explains the value of the lesson to the learner.	**In this course,** how often did you……:	1	2	3	4	5	**In your ideal course,** how often would you like to ……:	1	2	3	4	5
b. In the above section, you are broadly interesting in the course because of the instructor's motivation.		1	2	3	4	5		1	2	3	4	5
c. In terms of course objectives, considering the variable needs of learners.		1	2	3	4	5		1	2	3	4	5
d. In terms of course objectives, Brainstorm different possible solutions to Engineering leadership training.		1	2	3	4	5		1	2	3	4	5
e. In terms of course objectives, Find additional information by your active attending.		1	2	3	4	5		1	2	3	4	5
f. In terms of course objectives, Learning event specified for what you need to know.		1	2	3	4	5		1	2	3	4	5
g. In the "Pre-Assessment" section(Determining what learners already know), Reveal learners' interests and Consistent with it.		1	2	3	4	5		1	2	3	4	5
h. In the above section, Identify learners who can be resources within the class.		1	2	3	4	5		1	2	3	4	5
i. In the above section, Allow learners to express their needs for review or clarification.		1	2	3	4	5		1	2	3	4	5
g. In terms of participatory learning, Make individual or group presentation to the class.		1	2	3	4	5		1	2	3	4	5
k. In terms of participatory learning, Work in assigned groups to complete projects or other task.		1	2	3	4	5		1	2	3	4	5
l. In terms of participatory learning, How often did you ask the instructor questions during class?		1	2	3	4	5		1	2	3	4	5
m. In terms of participatory learning, Learner activities anticipated.		1	2	3	4	5		1	2	3	4	5

n. In terms of participatory learning, Experience the diversity of a contemporary classroom		1	2	3	4	5		1	2	3	4	5
o. In terms of participatory learning, Be graded on your class participation.		1	2	3	4	5		1	2	3	4	5
p. In summary, Using questions and question sequences effectively during a lesson.		1	2	3	4	5		1	2	3	4	5
q. In summary, Connect with colleagues from a range of disciplines.		1	2	3	4	5		1	2	3	4	5
r. In summary, Practice a variety of instructional strategies and techniques.		1	2	3	4	5		1	2	3	4	5
s. In summary, Giving and receiving constructive feedback.		1	2	3	4	5		1	2	3	4	5
t. In summary, Solve problems that have more than one correct answer.		1	2	3	4	5		1	2	3	4	5