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Does the Active Learning Help Students Learn and Improve the Performance? A Case Study of Engineering and Management

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Abstract

Active learning in any field of study is a time-demanding approach to engaging students in problem-solving and other activities in face-to-face class settings and online environments. The origin of learning is rooted in the activity, which is doing something to find out about specific topics. Active learning constitutes a natural pair in any education, especially in engineering and management. Engineering and management students are trained to design and construct solutions to problems in the real world. This paper presents the perceptions and attitudes of students who participated in active learning activities of civil/environmental engineering and construction management courses in fall 2021. One course from the Civil and Environmental Engineering curriculum (*Introduction to Environmental Engineering*) and another course from the Construction Management curriculum (*Construction Quantity Surveying*) were selected. Problem-solving in the class as a part of course delivery was performed in each topic of the courses as a part of the active learning activities. At the end of the semester, a survey with three Likert-scale questions was conducted, and the data was analyzed to determine the students' perceptions and attitudes about active learning in terms of their learning experience and performance in the exam. The final grades were also analyzed and compared with previous similar semesters' data for both the courses to predict the effect of active learning activities. Although statistically, the difference was insignificant, students' perceptions and attitudes were positive. Their performance in the examination was better with active learning course settings than those without active learning course settings.

Key Words: Perception and attitude, active learning, performance, improvement, engineering, and management education

Introduction

Active learning is one of the learning strategies used in different settings of course offerings in any discipline. Active learning engages and challenges students using real-life and imaginary situations where students engage in such higher-order thinking tasks as analysis, synthesis, and evaluation[1]. In another way, active learning is a broad concept used to refer to educational approaches designed to make students participate rather than passively listen. According to Felder and Brent "anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes"[2]. Active learning can also be defined as any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing[3]. The philosophical and pedagogical underpinnings of active learning in engineering education have been elaborated in a study where active learning is defined as a tautology[4]. This study argued that it is not possible to learn unless the brain or body is active in some way or other and further highlights that learning is an action, which results in a discernible change in what we know, or can do, or value. Evidence that learning is an activity by nature can be found in the etymological origin of the word. The etymological roots of the word ´learning´ go back to the activity of finding a track[4]. Kolb's learning cycle (Figure 1) also includes active experimentation as one of the essential elements of the learning process. A study by Shaharanee et al.[5] used the Technology Acceptance Model (TAM) to measure the effectiveness of the learning activities about 100 valid responses from the students indicated that most of the students were satisfied with the Google Classroom's tool that were introduced in the class. Results of data analyzed showed that all ratios are above averages, in particular, comparative performance was good in the areas of ease of access, perceived usefulness, communication and interaction, instruction delivery and students' satisfaction towards the Google Classroom's active learning activities[5]. TAM was developed by Davis[6] to explain computer-usage behavior. There are two critical determinants of the actual system used: perceived ease of use (PEOU) and perceived usefulness (PU). A study by Berlanga and Garcia-Penalvo[7] used active methodologies in flipped classrooms. It concluded that due to the diversity of students' knowledge and expertise, dialogic interactions between them foster a deep concept understanding, linkage and contribution to collective intelligence establishment between students and teachers. Another study[8] meta-analyzed 225 studies that reported data on examination scores or failure rates when comparing student performance in undergraduate STEM courses under traditional lecturing versus active learning. The effect sizes indicated that, on average, student performance on examinations and concept inventories increased by 0.47 SDs under active learning (n = 158 studies), and that the odds ratio for failing was 1.95 under traditional lecturing (n = 67 studies). These results also indicated that average examination scores improved by about 6% in active learning sections and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning. Problem-based learning presents the most difficult method to analyze because it includes a variety of practices and lacks a dominant

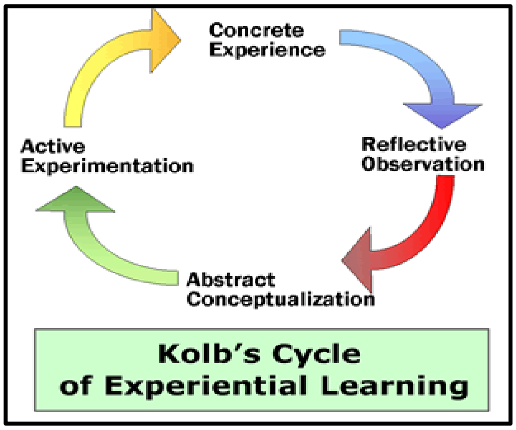

Figure 1: Kolb's learning cycle (reproduced from Ref.[4]).

core element to facilitate analysis and rather, different implementations of PBL emphasize different elements, some more effective for promoting academic achievement than others[9]. Faculty adopting PBL are unlikely to see improvements in student test scores but are likely to positively influence student attitudes and study habits. Studies also suggest that students will retain information longer and perhaps develop enhanced critical thinking and problem-solving skills, especially if PBL is coupled with explicit instruction in these skills[9].

This study was designed to answer a question: What are the students' perceptions and attitudes about the active learning for engineering and management type of courses? Two courses (CE 3702- Introduction to Environmental Engineering and CM 3410 - Construction Quantity Surveying) from the civil engineering and construction management programs were used in the fall 2021 to implement this study. An objective was formulated to understand the students' perceptions and attitudes about active learning and their performance. The objective was accomplished via anonymous online and face-to-face surveys and statistical analyses of the collected data. The overall goal of this study was to understand the overall effect of active learning on students' perceptions and attitudes as well as performance improvement in face-to-face (F2F) class settings.

Study Methodology

The active learning that was the practice, in this case, was the in-class multiple problems solving, covering the topic in a group of 2 or 3 after each topic of the course as a study conducted by the author[10] found that a group of 3 or 4 is optimum to perform better in a PBL course. So, the courses were set up for in-class problem-solving as a part of active learning instead of PBL. The instructors covered the class materials by lecturing and solving problems in the board for an hour or so and students were asked to solve problems for 15 to 20 minutes for a typical 75-minute class. During the in-class problem solving session, the instructor moved around to see each group's progress and helped as necessary to keep the groups on track. Although students were allowed to work in groups, finally, they had to submit the solutions individually. The individual submissions were graded and used to give students bonus points for their final grades. All the sections and courses used in this study were taught either in hybrid or F2F. Repeated in-class problem solving for each topic of the courses was the only active learning option used. The active learning option was part of the syllabus, and the instructor explained on the first day of the class how these activities would be conducted and used for bonus grades. The instructors also informed the students about the survey conducted at the end of the semester. Since in-class problem solving was for the bonus points only, there were no modifications on the number of practice problems and type homework to balance time spent out of class.

The assessment instruments used to conduct this study were online or F2F surveys as preferred by the instructor and the final class grades. To understand the effect of active learning on the perceptions and attitudes of students' surveys were conducted at the end of the semester with three questions to compare the students' learning environment in the environmental engineering and construction management courses with bonus points for the in-class problem solving related to each topic of the course. The survey questions are presented in Figure 2. The first two questions were asked to understand the students' perceptions and attitudes about the course content and alignment. The third question introduced the active learning concept and its effect.

Q.1. Did tests reflect the material covered in the class?

a. Excellent (5)
b. Above Average (4)
c. Average (3)
d. Below Average (2)
e. Very Poor (1)

Q.2. Is there a good agreement between the course outline and the course content?

a. Excellent (5)
b. Above Average (4)
c. Average (3)
d. Below Average (2)
e. Very Poor (1)

Q.3. Do you think that active learning, such as in-class problem-solving, helped you do better in the course and learning the course materials?

a. Excellent (5)
b. Above Average (4)
c. Average (3)
d. Below Average (2)
e. Very Poor (1)

Figure 2: Survey questionnaire for the study

The data collected through the surveys were analyzed to understand the students' perceptions and attitudes about the course content and alignment, active learning, and the degree of learning. The data was collected for the fall 2021 semester. Of a total of 44 students enrolled in CE 3702, 29 (66%) responded to the survey questions, and a total of 24 students enrolled in CM 3410, and 10 (42%) responded. Overall, 39 students (about 57%) participated in the survey, and 29 students (about 43%) did not participate the study because the survey and the active learning exercises were not mandatory. The analysis of data was performed with simple statics and with excel for Goodness-of-fit tests such as ANOVA χ^2-tests, student t-Tests, and F-Tests, as necessary. The results of the data analysis are illustrated in the following section. Please note that some of the responses to questions/options/choices, as seen in the Figures, might not sum up to 100% as few students did not respond to all questions or selected all options or preferences.

Results and Discussions

Based on the responses to Q.1 (Figure 3), the participants liked tests reflecting the material covered in the class. Overall, about 45% of the participants chose "5", 34% chose "4" scales, 17% chose "3" scale, 3% chose "2" scale, and 0% chose "1" scale for CE 3702 with a weighted average score of 4.21 and about 80% of the participants chose "5", 20% chose "4" scales, 0% chose "3", "2", and "1" scales for CM 3410 with a weighted average score of 4.80. The weighted average score was estimated using the % of student responses as weight. The example weighted average score for CE3702-Fall2021 = (1x0%+2x3%+3x17%+4x34%+5x45%)/(0%+3%+17%+34%+45%) = 4.21.

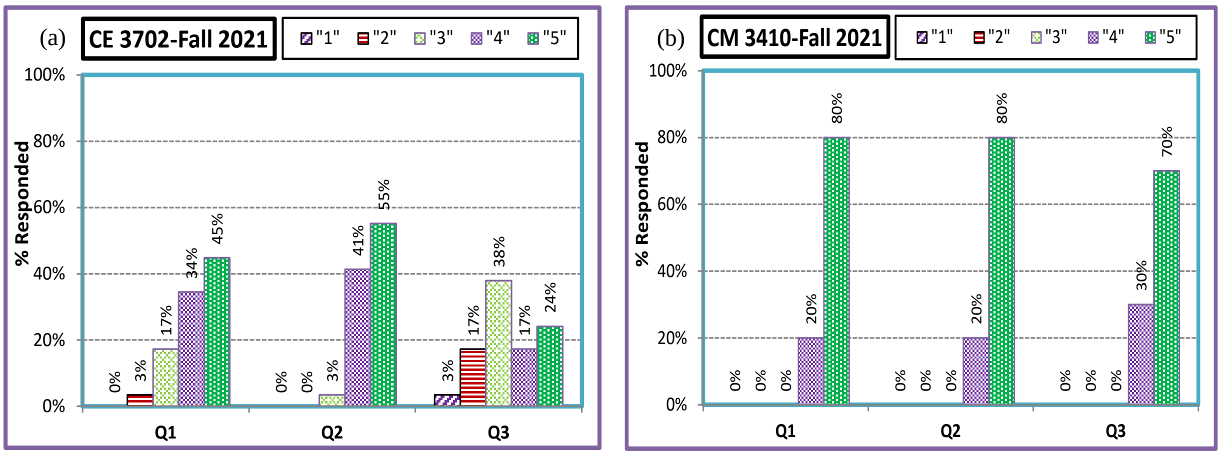

Figure 3: Distributions of responses to survey questions

Similar responses were observed for Q.2 for both the courses and the weighted average scores were close (4.52 for CE 3702 and 4.80 for CM 3410). Based on the responses to Q.3 (Figure 3), whether active learning, such as problem-solving in the class, helped the participants do better in the course and learning the course materials, overall, about 24% of the participants chose "5", 17% chose "4" scales, 38% chose "3" scale, 17% chose "2" scale, and 3% chose "1" scale for CE 3702 with a weighted average score of 3.41 and about 70% of the participants chose "5", 30% chose "4" scales, 0% chose "3", "2", and "1" scales for CM 3410 with a weighted average score of 3.41 with a weighted average score of 4.70. The weighted average scores for the courses varied widely for Q.3.

An assessment was performed based on the final grades to compare the effectiveness of the active learning for fall 2021 (with active learning) and fall 2019 (without active learning) for CE 3702 and fall 2021 (with active learning) and fall 2020 (without active learning) for CM 3410. The data is presented in Table 1 and Table 3. The weighted average grades are estimated based on the number of A, B, C, D, and F with a score of A=4.0, B=3.0, C=2.0, D=1.0, and F=0. For example, weighted average GPA for CE 3702-Fall 2021 = (10x4+23x3+9x2+0x1+2x0)/(10+23+9+0+2) = 2.8863 ≈ 2.89. Expected GPA is estimated as the total GPA for all semesters divided by the number of semesters (2.89+2.86)/2 = 2.87.

Table 1: Weighted average GPA with and without active learning options

Course	**Weighted Average GPA**	
	With Active Learning (w/AL)	**Without Active Learning (w/o AL)**
CE 3702	2.89	2.86
CM 3410	3.17	3.05

Based on Table 1 data, a single factor ANOVA was performed for the two groups (w/AL and w/o AL), and the results are presented in Table 2. Since $F<F_{critical}$, therefore, the null hypothesis cannot be rejected. Thus, the populations of the two learning options are statistically equal.

Table 2: ANOVA analysis for Table 1 data

Group	**Sum**	**Count**	**Average**	**Variance**	***Source***	***SS***	***DF***	***MS***	***F***	***p-value***	***F_{crit}***
w/AL	6.053	2	3.026	0.0392	*Between group*	*0.0055*	*1*	*0.0055*	*0.191*	*0.704*	*18.513*
w/o AL	5.904	2	2.952	0.0181	*Within group*	*0.0574*	*2*	*0.0287*	---	---	---

Based on the data in Table 3, chi-square tests were performed by course and the tests statistics are shown in the same Table. For CE 3702, a *p*-value of ***0.9903*** was obtained which is greater than both 0.05 (α = 5%) and 0.01 (α = 1%) and a χ^2-value of ***0.0001*** was obtained. For a degree of freedom (DF) of 1, the critical values for χ^2 are 3.84 (for α = 5%) and 6.63 (for α = 1%). The *p*-value is greater than both 0.05 (α = 5%) and 0.01 (α = 1%) and χ^2-value is less than critical values for both α = 5% and α = 1%. Therefore, null hypothesis cannot be rejected. This means, no significant differences could be observed in two learning options. The same conclusions can be drawn for CM 3410 course.

Table 3: Assessment based on final grades and weighted average GPA using Chi-square Goodness-of-fit test

Course	**A=4**	**B=3**	**C=2**	**D=1**	**F=0**	**Total**	**Weighted Average GPA**	**Expected GPA**	***p*-value**	**DF**	**χ^2-value**
CE3702-Fall2021	10	23	9	0	2	**44**	2.89	2.87	0.9903	1	**0.0001**
CE3702-Fall2019	9	18	5	0	3	**35**	2.86	2.87			
CM3410-Fall2021	12	6	5	0	1	**24**	3.17	3.11	0.9619	1	**0.0023**
CM3410-Fall2020	7	9	4	1	0	**21**	3.05	3.11			

Another assessment was performed based on the weighted average GPA for the two options for both the courses and all four semesters, and the data is presented in Table 4. A *p*-value of ***0.9992*** was obtained which is greater than both 0.05 (α = 5%) and 0.01 (α = 1%). A χ^2-value of ***0.0210*** was also obtained. For a degree of freedom of 3, the critical values for χ^2 are 7.81 (for α = 5%) and 11.3 (for α = 1%). The chi-square (χ^2) value obtained from the test is less than the critical values of both for α = 5% and α = 1%. Therefore, from both the χ^2-value and *p*-value point of view, the null hypothesis cannot be rejected. That means no significant differences exist in the grades with and without active learning options.

Table 4: Assessment based on weighted average GPA using Chi-square Goodness-of-fit test

Course	Observed GPAs	Expected GPAs	Statistics
CE3702-Fall2021	2.89	2.99	***p-value*** *= 0.9992* ***DF*** *= 3* ***χ^2-value*** *= 0.0210*
CE3702-Fall2019	2.86	2.99	
CM3410-Fall2021	3.17	2.99	
CM3410-Fall2020	3.05	2.99	
Total	**11.96**	**11.96**	

Since ANOVA and χ^2-test did agree, there is no need to run *t*-Test and F-test for further confirmation, however, *t*-Test and F-test for two groups, w/AL, and w/o AL, were run for additional verification. The *t*-Test performed for Weighted Average GPA ($p=0.704$, $t=2.919$, $t_{critical}=4.302$) also confirmed that the observed difference between the sample means is not convincing enough to say that the average weighted GPA between with and without active learning options differ significantly. The *F*-Test performed for the same groups ($p=0.38$, $F=2.165$, $F_{critical}=161.45$) also agreed with the *t*-Test. Therefore, it is further confirmed that no significant differences exist between the two learning options. Statistically, this study contradicts the summary results of 225 studies reported by Freeman et al.[8].

Students' perception was compared with their performance (weighted average GPA), as shown in Figure 4. For Figure 4, the weighted average GPAs were adjusted to a 5-point scale to match the Likert scale on the 5-point scale. The students' perceptions were collected via a survey with three questions: Q1 - Did tests reflect the material covered in the class?, Q2 - Is there a good agreement between the course outline (syllabus) and the course content?, and Q.3 - Do you think that active learning, such as problem-solving in the class, helped you do better in the course and learning the course materials? From Figure 4(a) there is no clear correlation between students' perceptions and performance in GPAs. However, Figure 4(b) shows positive trends, the increase of GPAs with all three perceptions.

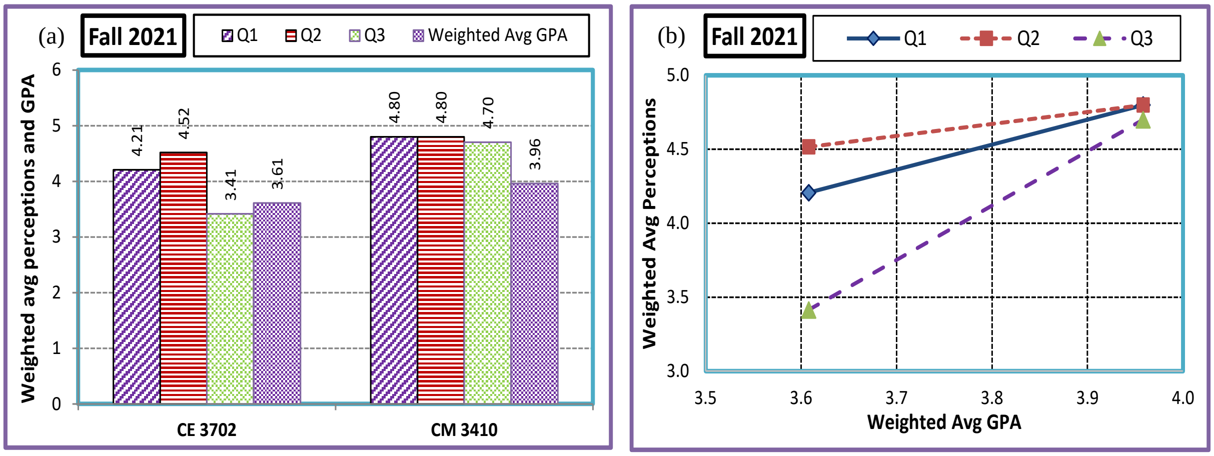

Figure 4: Correlations of students' perceptions and performances

Study Limitations

The main source of bias for this study could be that the authors were the only persons who designed this study, conducted the survey, collected the semester-end data, and analyzed the data. The evident conflict of interests and potential unconscious bias could genuinely affect the validity of this study. The other limitation could be the size of the data, as it is for only one semester. Several subjects in engineering and management fields, more faculty collaboration, and multiple semesters of study can generate more data that could make the study more dependable and conclusive.

Summary and Conclusions

In this paper, an effort was made to assess the perceptions and attitudes of students, which influence the learning environment as well as the effect of active learning activities, the in-class problem solving, and discussions in engineering and management. The courses `Intro to Environmental Engineering' from the Civil and Environmental Engineering curriculum and 'Intro to Structures and Construction Quantity Surveying from the Construction Management curriculum were used to conduct this study. In-class problem-solving as a part of course delivery was performed in each topic of the courses as a part of active learning. At the end of the semester, a survey with three Likert-scale questions was conducted. The data was analyzed to determine the students' perceptions and attitudes about active learning in terms of their learning experience and performance in the exams. The final grades were analyzed and compared with previous similar semesters' data without active learning activities for both the courses to understand the effect of active learning activities. Although statistically, the differences were not significant, students' perceptions and attitudes were positive and indicated the effectiveness of active learning. Their performance in the examinations was better with active learning course-setting than that without active learning course-setting. The authors plan to continue the study with several subjects in engineering and management fields along with other faculty collaboration and multiple semesters to generate sizeable data and make the study dependable and conclusive.

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Dr. Karim spent about six years as a full-time faculty at the Bangladesh University of Engineering and Technology (**BUET**) after he graduated from the same university in 1989. He came to the USA in 1995 and finished his Ph.D. in Civil/Environmental Engineering from Cleveland State University in 2000. He worked for about three years for ALLTEL Information Services in Twinsburg, Ohio, as an Applications Programmer. Then he worked for about eight years (in two separate times) for the Virginia Department of Environmental Quality (**VDEQ**) as a Senior Environmental Engineer and taught at Virginia Commonwealth University (**VCU**) as an Affiliate Professor before he went to Trine University in January 2008, as a full-time faculty of Civil & Environmental Engineering. He taught part-time at Indiana University-Purdue University Fort Wayne (**IPFW)** while employed at Trine University. During his time at Trine University, he taught an online course for VCU. He also taught at Stratford University, Richmond, Virginia campus as an adjunct faculty while working for VDEQ. Since the fall of 2011, Dr. Karim has been working for Kennesaw State University (**KSU**), Marietta Campus, Georgia, as a full-time faculty in Civil and Environmental Engineering. He served as an Assistant Department Chair and an Interim Department Chair of Civil and Environmental Engineering Department at KSU. He is a registered professional engineer for the State of the Commonwealth of Virginia and the state of Georgia. He has more than forty journal and proceeding publications and three professional reports in soil and sediment remediation, environmental management, waste treatment and management, wastewater treatment, statistical hydrology, project-based learning (PBL), and engineering education. He is a fellow of the American Society of Civil Engineers (**F.ASCE**), the American Society for Engineering Education (**M.ASEE**), and a Board-Certified Environmental Engineer (**BCEE**) from the American Academy of Environmental Engineers and Scientists (**AAEES**). He is also an ABET EAC Program Evaluation Volunteer (ABET EAC PEV) for both the civil engineering and environmental engineering programs.

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