Comparison of active learning models (ALM) on the achievement and retention of teaching mathematics

Ana Mae S. Dapin1*, Amelia T. Buan and Josie Vic Mendoza2

1Department of Science and Mathematics Education, College of Education, Mindanao State University- Iligan Institute of Technology, Iligan City, 9200, Philippines
2Integrated Development School, College of Education, Mindanao State University- Iligan Institute of Technology, Iligan City, 9200, Philippines

*Corresponding author’s e-mail address: anamae.dapin@g.msuiit.edu.ph

Abstract. Mathematics education can be daunting for students — due to a variety of societal factors and abilities in mathematics that are often seen as fixed. Teachers expressed that student – centered approaches promote active learning in the classroom. Active learning requires students to do meaningful learning activities and think about what they are doing. This study sought to find out the comparison of three active learning models (ALM) in relation to the achievement and retention in mathematics among Grade 11 students. This study was conducted in one of the private schools in Cagayan de Oro City during the first semester of 2018-2019 among 84 students under Science, Technology Engineering and Mathematics (STEM) strand. The results of the study revealed that the respondents from each model had significantly increased results of their achievement scores within the two weeks implementation. Furthermore, the three models had the same effect in terms of retention of mathematics concepts. During the focus group discussion students expressed that clear directions and giving feedback on their work helped them solve the problem. In addition, they also conveyed that listening to peers ideas motivated them to be successful in solving a problem.

1. Introduction
Mathematics has a language of its own. It is such a useful language and tool that it is considered one of the “basics” in our formal educational system. A number of students struggle in their Math subject for one reason or another. Creating an active mathematics classroom is a challenge for teachers [3] helping all students succeed in their learning is an enormous challenge that requires innovative thinking. Based on this knowledge, differentiated instruction applies an approach to teaching and learning that gives students multiple options for taking in information and making sense of ideas. Differentiated instruction is a teaching theory based on the premise that instructional approaches should vary and be adapted in relation to individual and diverse students in classrooms [10] [13] [14].

Teachers need to make sure that they challenge their students’ thinking. With active learning, students play an important part in their own learning process. They build knowledge and understanding in response to opportunities provided by their teacher. Active learning is generally defined as any instructional method that engages students in the learning process. Active learning contributes to the cultivation of transferable or generic skills, which are most in demand in industry. Students learn more by doing rather than by merely listening [2]. In addition to its academic advantages, active learning has been shown to produce numerous social and psychological benefits. A review of research on active learning found that it boosts development of critical-thinking skills and
fosters social interdependence and support among students [4]. Further, when compared with more traditional competitive or individualistic learning methods, active learning improves students’ attitudes toward their subject area, improves relationships between students, and improves student retention [9]. Active learning methods can be particularly beneficial in larger classes [6], which are increasingly common at the introductory level. As class size grows, it is often a challenge to include a significant number of students in class discussion. Alongside with this, the teacher’s ability to monitor students’ understanding inversely decreases relative to the class size. Using small cooperative-learning groups is an effective way to overcome these difficulties [11].

There are a variety of classroom models that can help frame what the instructor does to commence and conclude class. The events that occur during the instruction time: in the beginning, middle and end of class, can influence the engagements of students in their learning as well as their ability to synthesize major concepts in mathematics. Intentional questions, group discussions, and dynamic review can provide students with the time necessary to connect ideas and build larger conceptual understanding. Research suggests that when instructors make explicit connections between ideas and across class sessions, however briefly, students’ conceptual understanding and context-transfer rises exponentially [1]. The opening and closing moments of class can be effective moments for such connections.

Relationship between achievement and retention of students who are engaged in the curriculum with an exposure to different time frames of the teacher-led discussion has not been established yet in research. Thus, this study addresses the areas that are identified to be unexplored and need to be further studied. First, in this study, active learning is defined including the different types that are frequently discussed in Mathematics literature. A core element is identified for each of these types in order to differentiate between them, as well as to aid in the subsequent analysis in relation to achievement and retention of Grade 11 STEM students. Second, this study seeks to determine achievement and retention of students who are engaged in the curriculum which will later provide the comparative data on their retention. The comparison will be relative to the different time frames that the teacher exposes the students to the teacher-led discussion which is anchored on the Active Learning Models. Finally, it assists Math teachers in finding the most relevant literature in Active Learning which will be useful in making learners understand the topic through the teacher-led discussion.

2. Methods

This research study made use of the quasi-experimental pretest-posttest design with qualitative support for the perception. The achievement test consisted 30 items multiple choice which was validated by the two Mathematics teachers from Gusa Regional Science High School teachers who are experts in the field and with the research adviser.

The conceptual framework illustrates the figure 1 involving various active learning models wherein different time frame is given for the teacher-led discussions and active learning activities for the four active learning models. This study compared the achievement in General Mathematics and retention of learned mathematical concepts.

Furthermore, the above conceptual framework espouses the idea that Active Learning Models and the time-allotment are critical factors for students’ achievement and retention. The researcher based this assumption from Discovery Learning where learning takes place in the problem solving situations when learners draw on their own past experiences and existing knowledge to discover facts and relationships.
2.1. Subjects of the Study

A total of 200 Grade 11 students from the four sections of Science, Technology, Engineering and Mathematics (STEM) strand were considered as the research population. To ensure that the respondents are comparable across the four active learning models, matching was done based on their first quarter exam scores. Out of 50 students subjected to each active learning model only 21 students with a total of 84 were matched and considered as the research respondents for the four active learning models.

2.2. Implementation

This study was conducted for two weeks after which the same achievement test was given as post-test. Four learning models were described in Figure 2 Two weeks after the conduct of the study; the respondents took the parallel test for retention to find out which model(s) absorbed more of the learned concepts using the Active Learning Models. After the actual utilization of the ALM, the perception questionnaire was given to the respondents to get their insights on the four aspects, namely, the active learning method, the peer interaction, the assistant facilitator and the teacher.

Qualitative and quantitative data were gathered using the following Instruments: 1) Achievement Test. The researcher constructed a 50-item multiple-choice test based on the DepEd K to 12 learning competencies and adapted guide questions based on the previous exams in General Mathematics, particularly on the topic Simple and Compound Interest. A table of specifications was made to ensure that the competencies are met. The teacher-made test was evaluated for face and content validity by two Math teachers from a public senior high school, specifically, the Regional Science High School, and the researcher’s adviser. After face validation, for validity and reliability testing, the instrument was administered to the Grade 12- ABM students, item-analyzed and reduced to a 30-item test that met the criteria for validity. A retention test for measuring the retention of learned concepts was also made by the researcher based on the achievement test which was also validated by the same teachers and the research adviser. The test was validated using the Kuder-Richardson Formula 20 (Kr-20) and found to have a coefficient of reliability of 0.86.
Figure 2. Time Allotted for Teacher-Led Discussion across the Active Learning Classes In the Active Learning Model.

The index of difficulty and discrimination for each item was also being determined. The 30-item achievement test was given as pretest and posttest to the respondents for 1 1/2hours. The retention test was given after two weeks of the implementation to determine if learners could still remember their learned concepts. 2) Active Learning Course Module the teacher-researcher adapted the course module provided by the school as the lesson guide wherein the students are actively involved in the exploration of the lesson in relation to their own attitudes and values. In the process, one teacher is in charge of three to four simultaneous classes, wherein the teacher-researcher is conducting a discussion in one class while other classes perform tasks as supervised by assistant facilitators. Given the allotted time of 80-minutes to be consumed, 5-minutes is for the brief review of the activity to be answered, another 15-minutes to copy the concept notes, 20-35 minutes for an active learning activity, 5-minutes for the feedback or the evaluation of the lesson, and the last 20-minutes is for the teacher’s instruction. This will show how active learning method is done with consistency across the classes. 3) Perception Questionnaire. The Perception Assessment Questionnaire which contains four open-ended questions to determine the respondent’s insights as regards active learning, peer interaction, involvement of the assistant facilitator and the teacher’s role in the teacher-led discussion. This questionnaire was used as a guide in a focus group discussion.

3. Results and Discussions

3.1. On Achievement

Achievement is defined here as the gain scores from the achievement tests administered before (pretest) and after (posttest) the discussions; that is, \(\text{achievement} = \text{posttest score} - \text{pretest score}\).

Table 1. Comparison of Achievement Scores among Active Learning Models.

| Active learning models | Mean achievement scores | Standard deviation | 95% confidence interval | t statistic | p-value (two tailed) |
|------------------------|-------------------------|--------------------|-------------------------|------------|---------------------|
| ALM1                   | 4.52                    | 3.40               | 2.98 – 6.07             | 6.097      | p < 0.05            |
| ALM2                   | 4.81                    | 2.09               | 3.86 – 5.76             | 10.553     | p < 0.05            |
| ALM3                   | 6.00                    | 3.07               | 4.60 – 7.40             | 8.968      | p < 0.05            |
| ALM4                   | 8.10                    | 2.23               | 7.08 – 9.11             | 16.606     | p < 0.05            |
Table 1 shows the Mean and the standard deviation of the achievement scores. Computation shows the mean achievement scores to be as low as 2.98 in ALM1 and as high as 9.11 in ALM4. ALM4 got the highest mean of 8.10 in which in this model the teacher-led discussion was done in the last 20-minutes of the 80-minute class compared to those models which had their teacher-led discussion done before or in between the active learning activities.

Table 2. Comparison of Achievement Scores among the different Active Learning Models.

| Sources of variations in ALM | Sum of squares | Mean square | F statistic | p-value |
|-----------------------------|----------------|-------------|-------------|---------|
| Between sections            | 166.00         | 55.33       | 7.301       | P < 0.05|
| Within sections             | 606.29         | 7.58        |             |         |
| Total                       | 772.286        |             |             |         |

Table 2 shows the comparison of the achievement scores of students exposed to various active learning models. The analysis yielded a computed F ratio of 7.301 with p-value < 0.05. This led to the rejection of the null hypothesis that states: There is no significant difference in the achievement of students exposed to various Active Learning Models. This means that there is sufficient evidence to conclude that the achievement scores of the students have a highly significant difference relative to their exposure to various active learning models. Post hoc analysis was done to determine which models have significant difference in terms of achievement. Pairwise comparison test (Scheffe) was used to identify which pairs of models differs significantly.

Table 3. Comparison of Achievement on the Active Learning Models.

| Pairs of active learning models | Difference (I-J) | p-value | Interpretation |
|---------------------------------|------------------|---------|----------------|
| ALM1 (I) ALM4 (J)              | -3.571           | 0.001   | Significant    |
| ALM1 (I) ALM3 (J)              | -1.476           | 0.394   | Not significant|
| ALM1 (I) ALM2 (J)              | -0.286           | 0.990   | Not significant|
| ALM4 (I) ALM3 (J)              | 2.095            | 0.117   | Not significant|
| ALM4 (I) ALM2 (J)              | 3.286            | 0.003   | Significant    |
| ALM3 (I) ALM4 (J)              | 1.190            | 0.582   | Not significant|

Table 3 shows the comparison of achievement on the active learning models and further analysis done using the paired t-test in determining which paired models differ significantly and which do not. Pairwise comparison test identifies only two pairs of models to be significantly different from each other in terms of achievement. Pairs ALM1 & ALM4 and ALM2 & ALM4. This means that ALM4 where the 20 minutes teacher led discussion was done during the last 20 minutes of the 80 minutes class differ significantly with ALM1 and ALM2 where the teacher led discussion was done in the first 20 minutes of the class. This study supports the research result on active learning atmosphere is more favorable when students work together rather than compete and work against each other [5]. In view of this, instructors must become skilled themselves to give a better way in implementing new active learning strategies in their own classrooms that promote peer instruction and foster activity [12].

3.2. On Retention
Retention here is measured in terms of the difference between the scores in the Achievement Posttest and the Retention Test administered two weeks later. Analyses on the retention scores are similar to that performed on the achievement scores.
Table 4. Comparison of Retention Scores among Active Learning Models.

| Active learning models | Mean achievement scores | Standard deviation | 95% confidence interval | t statistic | p-value (two tailed) |
|------------------------|-------------------------|--------------------|-------------------------|------------|---------------------|
| ALM1                   | 3.67                    | 2.11               | 2.71 – 4.63             | 7.980      | p < 0.05            |
| ALM2                   | 4.81                    | 2.08               | 3.45 – 6.16             | 7.404      | p < 0.05            |
| ALM3                   | 4.67                    | 2.06               | 3.32 – 6.01             | 7.236      | p < 0.05            |
| ALM4                   | 4.10                    | 2.21               | 3.09 – 5.10             | 8.486      | p < 0.05            |

Table 4 shows the summary of retention scores and t-test of each model estimated at 95% level of confidence. The results imply that for each model there is a significant difference between the retention test scores and the posttest scores. The highest mean retention is ALM2 (M=4.81, SD=2.08) and the lowest retention score is that of ALM1 (M=3.67, SD=2.11). Apparently, this would mean that students in a teacher-dominated classroom, such as ALM1 where the students first had their teacher-led discussion before the active learning activities, had low retention. This study supports the research result that peer discussion fosters greater retention of learning [8].

3.3. On Student’s Perception

Students believe that active learning helped them understand the activities as well as the lessons better and mentioned three things to support their thinking. First, it helped them have the proper mind set needed, enhanced and developed independent thinking among them, and, because they are more active in the classroom they do not get bored. The students also think that the assistant facilitators did their best to help them. They gave the students clear instructions, prepared the materials for the day, entertained their needs in the classroom and encouraged them in their studies. The students recalled that during the teacher-led discussion, the teacher gave clear instructions, feedbacks on their work; more examples related to the problem they were solving showing them easier steps, and related the problems to the real world and why need to solve those problems in math. This result confirmed the result that in an active learning classroom, students perceived teachers’ guidance helped them resolved issues and challenges in solving problem [7]. Students also added that their peers gave them support especially when a problem needs clear brainstorming through exchange of ideas. Students think it was fun to be discussing with peers and they motivated each other to work well to be able to come up with their answer.

4. Summary of Findings

After the implementation of the study, the respondents from each model had significantly increased results of their achievement in the pretest and posttest which means that they understood the lesson given the different time schedules wherein teaching through Active Learning was done. Furthermore, the retention of the students measured after 2 weeks showed that there was a significant difference in their posttest and retention test scores.

ANOVA test results showed that not all the four models had the same achievement test scores as there was a significant difference shown in their gain scores. However, no significant difference among the four active learning models was found in terms of their retention.

Therefore, in the use of various Active Learning Models it may be done randomly in terms of the time schedule of the teacher-led discussions every meeting so that other students can also perform actively, not necessarily on the basis of a routine schedule.

The following are the findings of this study:

1. There is a significant difference in the achievement test in pretest and posttest on the different active learning models.

2. The model where the teacher-led discussion was done in the last 20 minutes of an 80-minute class period has the highest mean achievement score among the four models. Two pairs of models
ALM1 & ALM4 and ALM4& ALM2 are found to be significantly different from each other on the achievements.

3. There is a significant difference between the parallel test scores and posttest scores for each model; however, there is no significant difference on the mean retention scores among the four models.

5. Conclusions
Based on the findings of the study, the following conclusions were drawn;
1. The use of various Active Learning Models enhanced the students’ understanding in math using the different time allocation;
2. There was a significant difference in the achievement among the four active learning models.
3. There was lack of sufficient evidence to show that the retention scores of the students differed, that is, student retention of the lesson was not affected by the difference in the time frame of the conduct of the teacher-led discussion in the various Active Learning Models.
4. The perception results of the respondents showed that active learning helped them easily understand the activities with the guidance of the assistant facilitators. It was a big help for them that they can share their knowledge and thoughts in answering the activities with peers.

6. Recommendations
Based on the findings and conclusions, the use of various Active Learning Models in teaching General Mathematics is recommended as the ALM improves the respondents’ working independently with a guided module and also enhances their problem solving and critical thinking skills. However, it is also recommended that the prospective teacher-user or future researchers may;
1. Conduct an in-depth research on how peer assessment may be optimized to enhance collaboration among students in the classroom.
2. Make use of varied teaching strategies that will help the teacher in maximizing the 20-minute teacher-led discussion so that in turn, students understand the lesson given within this span of time.
3. Randomly does the active learning model in the different sections so that equal opportunities to the different time-allotment of the teacher-led discussion will be experienced by the students and not rely on routine activities.

References
[1] Ambrose Bridges, Lovett M, DiPietro M & Norman M, 2010 How Learning Works: 7 Research – Based Principles for Smart Teaching San Francisco: Jossey-Bas
[2] Bernido Christopher C. and Carpio-Bernido Victoria M. 2002 “The CVIF Dynamic Learning Program: Achieving Performance Targets with Strategic and Efficient Learning” Research Center for Theoretical Physics Central Visayan Institute Foundation Jagna, Bohol 6308 Philippines
[3] Corpuz B, January-June 2014 “Project-Based Learning and Problem-based Learning Compared” The Professional Teacher Vol. V. 1, 10-11
[4] Hains Wesson, R. 2013 Development of the problem-solving teaching resource: Figure 1: An example of common foundational steps in order to solve problem Melbourne Vic: Deakin University
[5] Ryan Hannah, 2013 ”The Effect of Classroom Environment on Student Learning” Honors Theses Paper 2375
[6] Ndebele C. and Maphosa C. 2013 Promoting Active Learning in Large Class University Teaching: Prospects and Challenges University of Venda, Centre for Higher Education Teaching and Learning, Thohoyandou South Africa
[7] Medina, J., Buan, A. & Managing, R.J 2018 Trash to math: Integrating environmental education in teaching grade 8thInternational Conference on Educational Research: Innovations for Capacity Building and Networking (pp. 157-172) Thailand: Faculty of Education, Khon Kaen University
[8] Sousa, D. A, 2006 *How the Brain Learns* Heatherton, Vic: Hawker Brownlow Education
[9] Terpstra, J.E. & Tamura R 2007 *Effective Social Interaction Strategies for Inclusive Settings. Does Active Learning Work? A Review of the Research* 
[10] Tomlinson, C. A., & Allan, S. D 2000 *Leadership for differentiating schools and Classrooms* Alexandria VA: ASCD 
[11] Weimer &.Cooper, J., & Mueck, R, 1990 *Student involvement in learning: Cooperative Learning and College Instruction* Journal on Excellence in College Teaching, 1, 68-76, 
[12] Webb, N. M. 2008 *Learning in Small Groups* In T. L. Good (Ed.), 21st Century education A reference handbook (pp. 203-211) Los Angeles: Sage 
[13] CD Ebal Jr, MJF Luga, MRO Flores, DJP Zabala, AT Buan, C Yuenyong 2019. Linear Equations in Two Variables STEM Education Learning Activities: Developing the Household Power Consumption Calculator App. *Journal of Physics: Conference Series*, 1340 (1), 012048 
[14] PM Jackaria, A Buan, C Yuenyong 2019. Students’ Performance in Context–Based Lessons in Mathematics Classroom. *Journal of Physics: Conference Series*, 1340 (1), 012047