# USING ACTIVITY-BASED COOPERATIVE LEARNING MATERIALS TO DEVELOP HIGH SCHOOL STUDENTS' CRITICAL THINKING AND PROBLEM SOLVING SKILLS IN STATISTICS AND PROBABILITY

Judella Y. Langcauon and Enriqueta D. Reston, Ph. D.
University of San Carlos
Cebu City, Philippines
judellalangcauon@gmail.com

*This study used quasi-experimental pretest-posttest design to investigate the use of activity-based cooperative learning materials in developing students' critical thinking and problem solving skills as twin goals in K to 12 Mathematics curriculum in the Philippines. Critical thinking assessment involved five items on reasoning with data using Measures of Variability. Results showed significant posttest gains in the explanation/reasoning component and in the overall critical thinking scores ($p < 0.001$). Students' problem solving performance in Probability of Events was assessed using Adamovic and Hedden's Level of Problem Solving Skills Guide where shifts in problem solving levels were evident after the intervention. The results indicated that engaging high school students in activity-based cooperative learning materials in Statistics and Probability may develop their critical thinking and problem solving skills.*

## INTRODUCTION

According to Schoenfeld (2002), learning mathematics need to go beyond content mastery. Students need to learn to think mathematically; they need to be able to think critically and solve problems confidently. With its general goal of producing "holistically developed Filipinos with 21st century skills", the K to 12 Basic Education Curriculum of the Department of Education has focused on developing critical thinking (CT) and problem solving (PS) as the twin goals for teaching mathematics.

One of the underlying learning principles and theories supporting the K to 12 Mathematics curriculum is cooperative learning. There have been many researches linking the use of cooperative learning on classrooms with the development of CT and PS skills. CT occurs and progresses as a result of the interaction processes with the teacher/peer/expert in the form of a dialogue before it is formulated by the student (Rabu, Aris, & Tasir, 2013). Similarly, in cooperative-group PS, students can share conceptual and procedural knowledge, and request clarification and explanation from one another, thus a better solution emerges than could be achieved by individuals working alone (Heller, Keith, & Anderson, 1997).

In this paper, the researcher investigated on the use of activity-based cooperative learning materials (ABCLM) in developing critical thinking and problem solving skills among Grades 7 and 8 students in Statistics and Probability, one of the learning domains in the K to 12 Mathematics curriculum.

## METHOD

### *Purpose*

Activity-based cooperative learning materials were used to teach the topics of Variability and Simple Probability of Events to Grades 7 and 8 classes, respectively. Pre- and post-assessments of critical thinking and problem solving skills were administered to the students in the two groups to determine if significant difference between the results exist. The implementation of the lesson using the ABCLM was done within the 4$^{th}$ quarter of AY 2016-2017 where the Statistics and Probability learning domain was indicated in the K to 12 Mathematics Curriculum Guide.

### *Sample*

The classes for the experimental groups were one intact Grade 7 class with 46 students and one intact Grade 8 class with 35 students. These classes were taught by teachers who participated in a Statistics and Probability workshop using the activities.

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*The Activity-Based Learning Materials*

The activities were part of an 8-session workshop for Teaching Statistics and Probability in the K to 12 Junior High School Mathematics Teachers held at University of San Carlos - Science and Mathematics Education Department and were published in an activity resource book entitled *Teaching and Learning Statistics and Probability through Activities* (Reston, 2016). For teaching the Measures of Variability in Grade 7, the activity entitled "*Which Team Would You Want to Be In?"* , the students analyzes the variation of two sets of test scores which was generated in class through the conduct of a quiz bowl with representatives for each team. For the teaching of Probability of Events in Grade 8, the activity entitled "*Probability Fair: Celebrate the Possibilities*" engaged the students in a classroom event where there are four experimental set ups where students in groups take turn for each set up to conduct a statistical experiment, record the results and calculate the probability of outcomes of pre-defined events. Then the groups compared outcomes across the four experiments and identified patterns in the outcomes.

*Instrumentation*

The adapted and researcher-developed instruments that were used are as follows:

*Levels of Problem Solving Skills Guide* is an instrument adapted from a model used by Adamovic and Hedden (1997) which categorizes the student's problem solving skills into six levels. These levels are: 1) non-analytical stage, 2) number writing stage, 3) symbol association stage, 4) early analytical stage, 5) simple analytical stage, and 6) complex analytical stage.

*Scoring Guides* are researcher-made instruments used to evaluate students' output in both pre- and post-assessments. The scoring guides for the test in Statistics and test in Probability have different criteria with a total of 20 points per test. The critical thinking scores consisted of two components in terms of (1) accuracy or correctness of answer, with one point for each item; and (2) reasoning or explanation that justifies their answers, with no point for no reason or absolutely nonsense reasoning, one point for attempted reason with data, two points for partially correct reasoning using measures of central tendency or variability, and three points for fully sound reasoning based on descriptive measures for the correct answer. The problem solving scores also consisted of two components: (1) correctness of answer, with one point for each item; and (2) solution, with no point for no solution, one point for partially correct solution, two points for correct solution with calculation but no probability equation, and three points for fully correct solution with probability equation.

RESULTS

*Assessment of Students' Critical Thinking with Data*

This assessment was conducted before and after using the ABCLM on the topic, Measures of and Variability. Table 1 shows the mean and standard deviations of students' total scores for both pretest and posttest. The results indicate that students may be better at answering objective questions than in reasoning with data to explain their answers, which is a mark of critical thinking. After the implementation of the ABCLM, the students' critical thinking, based on the criteria of scoring, somehow improved. However, more time for cooperative learning activities may be needed to improve further students' critical thinking and reasoning with data.

Table 1. Pretest and posttest assessments of critical thinking before and after the cooperative learning activities

| | No. of Students | Accuracy/ Correctness | | Reasoning /Explanation | | Total Score | |
|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | M | SD |
| Pretest | 46 | 2.7 | 1.0 | 1.9 | 1.2 | 4.6 | 1.9 |
| Posttest | 39 | 2.9 | 1.1 | 3.5 | 2.2 | 6.5 | 2.7 |

*Students' Problem Solving Performance in Levels*

A scoring guide was used in evaluating scores and a model by Adamovic and Hedden (1997) was used in determining students' level of PS skills. In the pre-assessment, most students got low scores and low levels because of their incomplete solutions to the problems. In the post-

assessment, students performed better in terms of solving the probability problems. Table 2 shows the distribution of student across each of the six levels for both pre- and post-assessments.

Table 2. Distribution of students according to problem solving levels before and after ABCLM

| Level | Pre-Assessment | | Post-Assessment | |
|---|---|---|---|---|
| | no. | % | no. | % |
| 1 | 1 | 2.8 | 0 | 0 |
| 2 | 17 | 48.6 | 6 | 17.1 |
| 3 | 0 | 0 | 0 | 0 |
| 4 | 17 | 48.6 | 16 | 45.8 |
| 5 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 13 | 37.1 |
| Total | 35 | 100.0 | 35 | 100.0 |

## DISCUSSION

*Analysis of Learning Gains in the Pre-Post Assessments in Critical Thinking*

Results of comparisons of pre- and post-assessments of students' CT were analyzed in terms of learning gains. A learning gain is defined as the positive difference in the post test and pretest scores. The descriptive statistics for the learning gains and the results of the paired t-test for significance of the learning gains are shown in Table 3.

Table 3. Learning gains for critical thinking

| Components | Learning Gains | | Computed t-value | p-value |
|---|---|---|---|---|
| | Mean | SD | | |
| Correctness/Accuracy | 0.1 | 1.3 | 0.480 | 0.3169 |
| Explanation/Reasoning | 1.4 | 1.7 | 5.141 | < 0.0001 |
| Total Score | 1.7 | 2.6 | 4.069 | < 0.0001 |

The results presented in Table 3 indicate that the learning gain for students' correctness of answer is small and not statistically significant at 0.05 level. However for the explanation component and total CT scores, the learning gains are statistically significant at 0.05 level. These significant differences indicate a generalizable result on the positive effect of the cooperative learning activity to the students' CT skills. This implies that the use of ABCLM helped improve students' reasoning/explanation and the total critical thinking score.

*Analysis of Learning Gains and Level Shifts in the Problem Solving Component*

For the PS skills, level shifts were analyzed in the pre- and post-test scores where a positive level shift indicates an improvement. The mean scores were also computed and analyzed and there was also an increase. Results show that students mean posttest scores after the activities were higher compared to the pretest scores. Table 4 shows the learning gains in correctness, solution and total scores after the implementation of ABCLM.

Table 4. Learning gains for problem solving

| Components | Learning Gains | | p-value |
|---|---|---|---|
| | Mean | SD | |
| Correctness | 0.4 | 0.8 | 0.005 |
| Solution | 1.8 | 2.8 | < 0.001 |
| Total Score | 2.2 | 3.2 | < 0.001 |

In addition to the improvement of scores based on answers and solutions, the students' different levels of problem solving performance also changed. After taking the post-assessment, most of the students shifted from a lower level to a higher level, while some remained on their levels. This is another implication of the positive effect of using ABCLM to improve the way

students solve problems. Figure 1 shows the distribution of students to groups representing their shift of levels from the pre- and post-assessments.

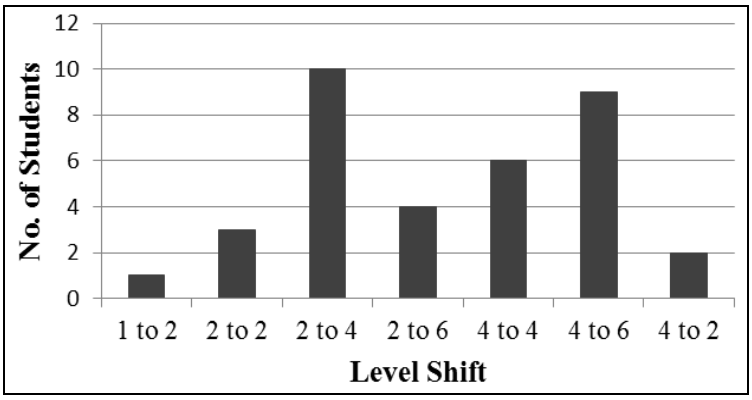


Figure 1. Frequency distribution of students as to their shift of PS levels

These differences in shifts categorized the students into seven groups. These cases showed a stationary, a positive, and even a negative shift of levels after the implementation. A positive shift from a lower level to a higher level was indicated by improvement on the way student solve the problems. A stationary case was indicated by same levels and sometimes same scores marked by inability to provide more detailed solutions. The negative shift was considered a rare case with only 2 out of the 35 participants in this level. Majority of the cases supports the positive result of the said intervention. These cases show the potential use of ABCLM on improving the level of PS performance of students.

## CONCLUSION

The results of this study indicated using activity-based cooperative learning materials in teaching Statistics and Probability lessons had the potential to develop students critical thinking and problem solving skills as they collaboratively and actively engage in real data sets to evaluate and make choices or solve problems The use of ABCLM after introducing a game to generate data in a Grade 7 class on Measures of Variability had improved students' open-ended explanations or reasoning with data to support their choices/answers as one indicator of critical thinking. Similarly, using ABCLM also improved Grade 8 students' problem solving skills and levels in the lesson on Probability. This study also strengthened the claims of other researches over the positive effects of cooperative learning in the teaching-learning process. Cooperative learning activities, when used effectively and efficiently, have the potential to develop these important skills. This study also contributes to the limited literature on teaching for critical thinking in Mathematics lessons.

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