Enhancing students’ level of thinking skills through integrative multi-Modal strategy in teaching mathematics

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Abstract. Mathematics teaching requires an in-depth content knowledge and skills in the delivery of the lessons. This study determine the effects of using the Integrative Multi-Modal Strategy (IMSS) on the level of thinking skills of two intact sections of third year high school students. The subjects of the study were carefully matched in pairs according to their previous grades in Math and English. A combined quantitative and qualitative method of research was employed. A researcher-made test consisted of a – 12 item open-ended problems in Mathematical Thinking Skills Test (MTST) was used. It was administered successively to both groups prior to the experimental instruction. Results showed that the difference in mean ranks in the level of thinking skills of the experimental and control group was found to be significant. The experimental group posted higher achievement in the MTST as compared to the control group. The overall performance of the experimental group in the MTST is better and attained the developed level of mathematical thinking. This strategy as used in a mathematics classroom, provides teachers the opportunity to develop IMMS activities that enhance students’ level of thinking skills.

1. Introduction
In recent years, the Philippines has lagged behind the rest of the participating countries in terms of education, particularly in Science and Mathematics. Based on the three rounds of the Trends in Mathematics and Science Study (TIMSS), which took place in 1995, 1999, and 2003. Filipino grade four pupils and second-year high school students struggle with their knowledge and skills in mathematics and science. Filipino learners’ functional literacy appears to be on the decline. The poor performance of Filipinos necessitates the immediate implementation of mathematics education changes that will target specific areas of difficulty in learning mathematics in the Philippines. However, before such reforms can be implemented, an extensive examination of Filipino students’ mathematics performance is required [1]. In recent decades, there have been considerable calls for reforms in mathematics education, particularly in classroom procedures. Teachers have been pushed to design instruction such that students participate in more collaborative, discussion-based activities with the goal of supporting a community of learners, rather than a group of individuals working on mathematics [2].

Despite the current state of our mathematical education, Filipinos have demonstrated outstanding performance and excelled in several international mathematical competitions. Filipino students have excelled in the number of international events, demonstrating their commitment to academic excellence. Teachers’ training is important in order to improve students’ mathematics skills and competency by providing them with effective and innovative problem-solving solutions. To resist the rigors of international mathematics competitions, intensive training builds higher-order thinking capabilities, cultivates creativity, and increases analytical ability.
Students who are exposed to an effective teaching and learning technique in mathematics gain a higher degree of conceptual understanding, logical reasoning, and spatial visualisation, which leads to improved performance in proving, problem solving, and mathematics [3]. Students' numerical scores and the quality of provided solutions and responses that show their critical thinking skills, conceptual understanding, and problem-solving abilities improve when they take a non-traditional method to addressing problems [4]. Simply defined, critical thinking is the ability to analyze and evaluate information. Critical thinkers pose important issues and problems, clearly formulate them, gather and evaluate relevant data, apply abstract concepts, think openly, and communicate effectively with others [5]. The Multi-Modal Strategy is an attempt to turn these modes into a method for teaching mathematics that is both systematic and practical. This methodology will emphasize connections between diverse types of representation, resulting in a deeper comprehension. It will emphasize a variety of experiences in order to make students' mathematics learning more enjoyable and challenging [6].

As a result, this research will hopefully be used to develop an effective teaching technique for mathematics that will improve students' thinking skills.

2. Methods

The effects of Integrative Multi-Modal Strategy in teaching Mathematics on students' level of thinking skills was investigated using a quasi-experimental pre-test-post-test/control group design. The study used two intact classes of third-year high school students from MSU-Balo-i Community College in Balo-i, Lanao del Norte, Philippines as samples. There were fifty-five (55) students in each of the two entire sections. This grade level had four sections, with the two portions in between being taken to check comparability before the intervention began. The general point average (GPA) grade in the second year level was used to classify students into classes in the third year level. In terms of mathematical and communication abilities, the two groups were equivalent based on their previous year's scholastic performance (grades) in Mathematics and English. From these two groups, thirty-three (33) matched pairs were obtained and considered research participants. Tossing a coin was used to assign each of the two intact classes to either the control or experimental group.

Two math experts in the field evaluated the face and content validity of the researcher-made Mathematical Thinking Skills Test (MTST). The 17-item MTST was pilot tested with a similar sample, and following item analysis, it was reduced to 12 items with a reliability coefficient of 0.814. The quantitative portion of the study focused primarily on determining the students' mean gain scores, as well as the significant difference and relationship between the two groups in terms of their level of thinking skills. The qualitative section of the study focuses on the students' qualitative manifestations and perceptions. The results were cross-validated using class observations, journal entries, interviews, and video recordings. Except for the IMMS group, which employed the IMMS Think Board, both groups were subjected to the same conditions.

During the experimental phase, the researcher taught two separate groups and scrupulously adhered to the planned lesson plans, which included activities tailored to each group. The teaching approaches employed in the two learning settings (experimental and control group) were IMMS and TLBF. Both groups received instruction in their regular classrooms. An IMMS Corner and Think Boards were posted in the experimental group's classroom as a learning aid for the students. With the presence of a teacher-observer, the class teaching was performed differently. In the IMMS environment, the six learning modes were used to solve a problem, as well as the IMMS-TB and worksheets. The activities (both indoor and outdoor) were designed to enhance the students' thinking skills. The classes in this context were taught using lesson plans that were designed for both groups. Students were given the chance to describe their responses as well as the steps they took to solve the problem.

The Traditional Lecture-Based Format setting followed a textbook approach and covered the same mathematical topics as the experimental group. The classroom atmosphere was developed around the teacher, who stood in front of the class and imparted knowledge to the students. Mathematical concepts were posted on the blackboard, and students were allowed to record them in their notebooks after solving various examples with drawings. This group of students were passive receivers.
In the conduct of the investigation, teacher-observers were regularly had close supervision of the activities in the learning environment. Students were given lesson check sheets to use as a diary entry. The teacher-observers and the researcher conducted informal interviews with both groups to discuss misconceptions and queries about the topics addressed. To capture the classroom dynamics during the session, the proceedings of the class instruction were audio and videotaped. The post-test was given at the end of the treatment period. A follow-up interview was chosen at random among the participants. To validate the data acquired throughout the intervention period, the interviews were videotaped, recorded, and transcribed. Both groups of students completed the same classroom instruction relevant to each class, were taught the same mathematical topic at the same pace, and were given the same number of assignments, problem sets, and exams.

To isolate the effects of the students' level of thinking skills, the researcher attempted to minimize the impacts of other variables such as change in instruction and specially developed activities for each group. All lecture outlines and exercises for each class were created by the researcher in accordance with the prescribed mathematics curriculum.

Following the same scoring criteria, the researcher and two mathematics teachers (inter-raters) checked the students' test papers. A scoring rubric created by the researcher was used to evaluate the quality of the respondents’ answers on the MTST items. The Mathematical Thinking Skills Test (MTST) consisted of a 12-item open-ended problem set that required a suitable solution and reasoning. Each question was designed to assess the cognitive process of comprehension, concept development, and generalization. This was used to assess student learning and the development of critical thinking skills. The inter-rater agreement was used to determine the students’ MTST scores, and performance level descriptors were assigned based on their test results.

### 3. Results and Discussion

The results are presented and discussed in the order of the research questions.

#### Table 1. Respondents’ pre-test test performance profile

| Group      | Test | Mean  | Standard Deviation | N  |
|------------|------|-------|--------------------|----|
| Experimental | MTST | 25.96 | 4.19               | 33 |
| Control    | MTST | 16.75 | 4.18               | 33 |

As indicated in table 1, the experimental group's pre-test performance profile in the MTST was higher, with a mean of 25.96, than the control group's mean of 16.75. The experimental group's MTST standard deviation is 4.19, while the control group is 4.18. Furthermore, the standard deviation of the experimental and control groups differs slightly which indicates that the two groups were comparable in their performance in the pre-test and signifies the start of the study. A review of the literature found that students in mathematics are lagging in problem solving and critical thinking skills [7].

#### Table 2. Respondents’ post-test test performance profile

| Group    | Test | Mean  | Standard Deviation | N  |
|----------|------|-------|--------------------|----|
| Experimental | MTST | 38.50 | 5.94               | 33 |
| Control  | MTST | 22.21 | 4.23               | 33 |

Table 2 shows the experimental and control groups' post-test mean scores in the MTST T, and it can be seen that there is a substantial difference between the two groups. Respondents in the experimental group averaged 38.50 on the MTST, whereas those in the control group averaged 22.21. When compared to a perfect score of 72 points, the MTST results were determined to be significant. The mean MTST score in the experimental group was 38.50, or 53.47% of the total number of points. When compared to the mean scores achieved in the experimental group's pre-test, the MTST result was consistently
higher. Table 2 also shows the MTST mean scores for the control group, which range from 16.75 to 22.21. Both groups' test results in the MTST were significant, and they showed improvement towards the end of the study period. For many students, an over-reliance on the chalk-and-talk method has resulted in poor performance and a negative attitude toward classroom mathematics. To increase understanding and flexibility in thinking, the multi-modal approach employs the six various modes of representation of mathematical information [8]. Participants in the IMMS research improve their mathematical proficiency and their level of thinking skills.

Table 3. Pre-test-post-test mean gain score in the mathematical thinking skills test

| Group      | Mean Gain | SD  | t - value | Sig. (2-tailed) | Decision     |
|------------|-----------|-----|-----------|-----------------|--------------|
| Experimental | 12.54     | 6.24| -8.882    | .000*           | Ho is rejected |
| Control    | 5.46      | 4.11|           |                 |              |

* Significant at 0.05 level of significance.

The computed t-value of -8.882 is significant at 0.05, as indicated in the table 3. The experimental group outperformed the control group on the Mathematical Thinking Skills Test, according to the t-test results. Further analysis of the mean gain scores acquired by the two groups reveals that, as demonstrated by the standard deviation values, they do not differ in the manner they answered the questions. In comparison to the Traditional Lecture-Based Format of teaching, the t-test result may indicate that IMMS in teaching Mathematics has a good potential to increase students' thinking capabilities. According to a study, teachers must first establish critical thinking before they can help their students acquire higher order thinking [9]. Our students can gain self-esteem and a deeper knowledge of mathematical ideas by participating in an activity that demands them to think and interact. If high school students have fully developed their geometric thinking at the lower level of visualization, analysis, and informal deduction, they can perform well in proof oriented geometry. The Van Hiele model may be a vital tool for geometry teachers to produce developmentally appropriate teaching content for high school students [10]. As a result, the students' mathematical thinking will progress to the developed or highly developed level.

Table 4. Comparison of sample statistics on mathematical thinking skills test

| Test                        | Experimental Group (n = 33) | Control Group (n = 33) | Mean Gain |
|-----------------------------|-----------------------------|------------------------|-----------|
|                             | Pre-test        | Post-test     | M      | SD  | M  | Pre-test     | Post-test     | M  | SD  |
| Mathematical Thinking Skills Test (MTST) | 25.96 4.19 | 34.61 5.94 | 12.54 |     | 16.75 4.18 | 22.21 4.23 | 5.46 |

Table 4 shows a comparison of the participants' performance in mathematical thinking skills. In the MTST, the experimental group has a mean gain of 12.54, whereas the control group has a mean gain of 5.46. In the MTST, there was a difference of 7.08 between the two groups' mean gain scores. Students in the experimental group scored higher on both tests and attained significant increases in their post-test mean scores when compared to their pre-test mean scores. The performance of students in the control group improved as well, though not as much as that of the experimental group. One could infer that the experimental group performed better and was better prepared mathematically. The findings are also consistent with a research in which students began by working on open-ended tasks that were designed to have numerous correct answers and were labelled as "incomplete" and "open-ended" [11]. Students are first given open-ended problems, after which they are provided many accurate answers to the given problem in order to get experience in discovering something new during the problem-solving process. The Geometry Standards, as stated in the study of [12], support it by extending recommendations to emphasize the utility of "geometric principles in describing and solving issues in other areas of
mathematics and in the real-world”. The improvement in participants' thinking skills as a result of using this method is linked to the increase in mean gain between the two groups. In quizzes, pretest, and posttest scores, the intervention appeared to outperform the traditional group in a study that corroborated the conclusions that the impacts of utilizing multi-modal interactive technique in teaching measurement on the achievement and attitude of Grade VI pupils [13].

Table 5. Comparison of students’ level of thinking skills

|                      | Experimental Group (n =33) | Control Group (n=33) |
|----------------------|---------------------------|----------------------|
|                      | Pre-test                  | Post-test            | Pre-test | Post-test |
| Mean Rank            | 48.06                     | 48.42                | 18.94    | 18.58     |
| MTST Pre-test        |                           |                      |          |           |
| Mann-Whitney U Test  | 64.00                     | 52.000               |          |           |
| Wilcoxon W Test      | 625.000                   | 613.000              |          |           |
| Z                    | -6.168                    | -6.330               |          |           |
| p-value              | 0.000                     | 0.000                |          |           |

The Mann-Whitney U Test was used to determine if the mean ranks of the two groups differed significantly. As indicated in the table 5 above, at the 0.05 level of significance, the test yields a significant result ($z = -6.330$, $p = 0.000$). The differences between the mean ranks of the two groups are statistically significant, as seen in the table. This means that at 0.05, the null hypothesis is rejected. The results suggest that students in the experimental group developed their thinking skills more than those in the control group due to their use of IMMS.

3.1. Students’ Perceptions in the use of IMMS in Teaching Mathematics

The introduction of the IMMS in the teaching of mathematics made a significant difference in the experimental group's learning. Throughout the intervention, the study gathered statements and questions from students through observation. Below are some of their sample statements and questions. These were supported by the students' journal entries in the form of lesson checks, the teacher-observers' observations and assessments, and the researcher's interviews with students and teacher-observers. The following are excerpts from the journals, students' worksheets, observation forms, and video recordings and interviews that have been transcribed.

**Write down one new thing/problem which you can do now?**

“On the topic of similarity and its application, I understand the number and symbol mode.

“I'm happy because I understand the lesson in proportionality and similarity, and I learned how to solve problems on proportionality”.

“I’d like to know more and master about the strategy that our teacher taught us”.

“I learned something and was able to solve many problems because I understand the lessons clearly with the use of IMMS”.

**The most difficult thing about this lesson.**

“The most challenging aspect of this lesson was the story mode, which I find difficult to create.”

“Well, I am confused how to apply the IMMS in the problem.”

**What did I like most about the lesson?**

“The lesson for me is easy to understand because the teacher explains about the mode of representation in teaching mathematics.

“Our lesson is engaging and encourages us to think and develop our creativity.”

“I like how the lessons are explained using the IMMS; the topics are interesting, but some of the problems are difficult for me to solve.”

**What I like least about the lesson?**
"I'm having trouble creating the story mode.

Reflective Insights

"The strategy or technique used is nice because it makes us understand the lesson"

"I like the IMMS"

"I understand the lesson easily because of the IMMS"

"IMMS has many techniques in teaching the lesson, it is clear and easy to understand"

"I like the way the IMMS used in the lesson. I hope I won't forget this technique so that I can answer in the exam"

"The strategy in teaching is very nice, although it is hard"

As mentioned in the study by [14], teachers have expressed a desire to get a better understanding of teaching work in order to enable involvement in such activity. This is supported by the study of [15] that, the story mode has a significant impact on student’s mathematical learning. In the teaching-learning of mathematics, IMMS introduced word and story mode to improve learners’ writing and speaking abilities. The research participants’ reflections revealed how the IMMS aided them in their mathematics learning, resulting in their realization that mathematics is an engaging subject when taught using an effective strategy.

4. Conclusion

In general, this research shows that IMMS is more effective than the traditional lecture-based format in improving students' thinking skills. Students in the experimental group performed better on the MTST during the post-test after the intervention. As a result, the overall performance of the MTST, which accounts for 20% or 60.6% of the sample performs better and attained at the developed level in favor of the experimental group. This shows that the IMMS have improved their critical thinking skills. This could indicate that the teaching strategy had an effect on their learning. The students responded positively to the use of the Integrative Multi-Modal Strategy – Think Board (IMMS-TB). By working through the various modes of representation, it improves their cognitive, affective, and psychomotor skills.

As a result, the overall performance of the MTST, which accounts for 20% of the sample or 60.6%, is better and more developed in favor of the experimental group. This shows that the IMMS have improved their critical thinking skills. This shows that the IMMS have improved their critical thinking skills. This could indicate that the teaching strategy had an effect on their learning. Consequently, a significant difference was found in the post-test scores between the experimental and control group of the MTST. This also implies that the experimental had better mathematical ability, as evidenced by their mathematics grade, which would indicate better test performance.

The null hypothesis is rejected because the difference in mean ranks in the level of thinking skills between the experimental and control groups was found to be significant. Students in the experimental group had more developed thinking skills than students in the control group. The findings support the theory that students with higher mathematical ability have a higher comprehension level when solving open-ended problems.

The students respond positively to the use of the Integrative Multi-Modal Strategy – Think Board (IMMS-TB). By working through the various modes of representation, it develops their cognitive, affective, and psychomotor domains. Students of all abilities, including the weakest, were able to contrive interesting stories. Students who use IMMS-TB find that learning geometry is more meaningful and enjoyable. In comparison to the traditional lecture-based format of teaching, IMMS appears to have a significant impact on mathematics and geometry in terms of thinking skills. IMMS, according to students, made geometry learning more meaningful and easy to understand.

5. References

[1] Aman J P 2006 An Assessment of Mathematical Communication Competency of Fourth Year Science and Non-Science High School Students Unpublished Masters’ Thesis (the Philippines: University of the Philippines Diliman Quezon City)
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