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# The Influence of Mathematical Communication on Students' Mathematics Performance and Anxiety

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**Abstract** Challenging students to communicate both orally and in writing in mathematics class help deepen their conceptual understanding, improve mathematics performance and reduce anxiety towards mathematics. This study was undertaken to determine the effect of mathematical communication on the mathematics performance and anxiety of high school students in Bulua National High School. Pretest-posttest quasi-experimental control group and qualitative research design were employed. Interviews were also done to verify responses for triangulation. Results of the analysis revealed that the students exposed to mathematical communication approach have significantly higher achievement, conceptual understanding and significantly reduced anxiety compared to the Dynamic Learning Program (DLP) approach. Hence, mathematical communication is effective in improving students' achievement, conceptual understanding, and reducing anxiety.

***Keywords:*** conceptual understanding, mathematical communication, performance

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## 1. Introduction

Mathematics education in the Philippines is facing a dilemma as shown in the low performance of students in international and national assessments in mathematics (TIMSS) [18] and National Achievement Test (NAT). The national performance of fourth year students in NAT from school years 2004 to 2013 were all below the 75% standard criterion set by the Department of Education in terms of achievement level which is the national target.

To address this problem, the Enhanced Basic Education Curriculum, K-12 program emphasizes conceptual understanding in teaching high school mathematics. This new curriculum stresses that conceptual understanding should be emphasized to master the three cognitive skills of the six facets of understanding which are explanation, interpretation and application, where communication and connection are given emphasis in students' written insights and reflection (DepEd Order No. 73, series 2012) [8]. The Mathematics Association of America (MAA) [15] also stipulated the development of students' precision in both written and oral communication to help them learn to present their analysis in clear and coherent arguments reflecting the mathematical sophistication appropriate to their mathematical level. Students should learn to communicate using the language of mathematics because if students can communicate mathematical procedures orally through discourse with their classmates and teachers, even to their family and friends, and in writing through journals or portfolios, then they have exhibited their understanding of the concepts studied and discussed in class. Communicating through oral, written and visual forms clarify and promote understanding of concepts and can be a vehicle for both teachers and students to appreciate mathematics (NCTM) [14]. It may also reduce students' anxiety toward mathematics. Thus, this study assessed the influence of mathematical communication on the students' achievement, conceptual understanding, and mathematics anxiety.

### 1.1. Communication through Writing in Mathematics

Communicating skills is the ability of the students to express their ideas, describe, and discuss mathematical concepts coherently and clearly. It is the students' capability to explain and justify action in procedure and process both orally and in writing. As Staver [17] pointed out that all that effect in learning can be promoted through interactions and communications. Challenging students to communicate both orally and in writing in mathematics class can help deepen their conceptual understanding. When students are encouraged to interact with others, they are able to construct individual understanding and concept formation. Bruner [4] also argued that communicating skills play a central role in the development of cognitive structures and that language is a means, not only for representing experience, but also for transformation of ideas. He asserted that improvement in language function produces improvement in certain kinds of problem solving skills and that activation of language habits that the child has already mastered may improve performance as well. Vygotsky [19] also asserted that the most important symbolic system supporting learning is language. He believed that language in the form of private speech, like talking to oneself or writing journal enhances cognitive development and argued that when young children are involved in private speech, they are communicating with themselves to guide their behavior and thinking. These private speeches can be later transmitted to important cognitive activities such as directing attention, solving problems, planning, forming concepts and gaining self-control.

NCTM standard [12] elaborated communications through written, oral and visual forms show clarity of understanding the ideas and concepts which will make students become interested in mathematics. Simple exercise in writing will not only clarify student's thinking but also provide other students fresh insights gained from viewing the problem explanation from a new perspective. Above all, writing can be useful in giving opportunities for students who are uncomfortable in oral recitation to express their understanding of concepts in class. However, it is revealed that writing in mathematics is not often used by teachers. Kadunz [9] stated that writing is more than just materialized speech and cited Maier's [11] statement that writing about one's own doing of mathematics offers a chance to learn mathematical concepts because students create their own texts of mathematical concepts. He further said that in some cases ideas itself can become a source of new form of concept in learning mathematics. Candice [5], Kuinisala [10] and Braga [3] also observed that writing fostered the belief that expressing students' ideas in writing is an important component in learning mathematics. They claimed that journal writing allow the students to be responsible for their own learning because it encouraged students to recognize their strengths and weaknesses and to self-assess their progress. They believed that students who keep journals in mathematics class can enhance their skills in communicating their understanding about the concept and give them opportunity to reflect on their own learning. Journal writing offers students opportunities for individual reflection and develop communication ability. It can also help students clarify their thoughts about mathematics and particular experience on their activity in class. The students who underwent journal writing could construct their own understanding of the concepts discussed and could clarify a specific activity in the classroom. These activities can foster students' positive attitudes towards mathematics, particularly if the journal entries are accompanied by discussions about any negative feeling and ways to deal with unpleasant experiences.

### 1.2. Communication through Discourse

Normally, mathematics teaching practices focus more on making students able to perform mathematical task and follow a certain procedure in solving problems. Few teachers ask students why certain procedure works in arriving at an answer and how these procedures were developed. Discussion on why such procedure works is always left out, even among students and peers on the mathematical processes. Sfard [16] suggested putting emphasis on discourse as medium of instruction. She redefined thinking as internalized communication. She coined the term 'commognition' from the terms cognition and communication. She asserted that thinking is subordinate to, and informed by, the demands of communication. Thus, organizing students in small group discussion to engage in mathematical task and to present their solutions to the class has the potential of promoting thinking process. These opportunities to communicate play an important role in mathematics learning. Amoncio [2] who studied the influence of commognition on Navajo students' in high school geometry believed that when students can fully communicate the way they think, teachers can do an excellent job in intervening at the level of their understanding and teachers can provide better opportunities for them to succeed. Polizon's [13] study revealed that student-to-student discourse is an effective teaching method in improving the achievement and conceptual understanding scores of students. Students who were exposed to student-to-student discourse had higher retention scores than students under the conventional reinforcement such as seatwork, board work and homework. These was supported by Allen [1] by stating that teenagers need to talk about mathematics and need to justify their thinking, this can only be achieved if they are given an opportunity to have discourse through cooperative groupings. She also cited the statements of Cohen [6], Willis [21] and Watanabe [20] that group work at the high school level gives mathematical and social benefits to students. They have more opportunities to articulate their thinking, exhibit deeper understanding and retention of concepts, welcome the ideas of others and incorporate them into their own strategies, feel less isolated and anxious about mathematics and communicate effectively by justifying their position through shared objective facts rather than emotional persuasion.

## 2. The Method

From among the 8 sections, 188 fourth year high school students in Bulua National High School, school year 2013-2014, were the participants of the study. Two intact classes with 94 students were randomly assigned as the experimental group and the other two groups with 94 students as control group composed of 47 students in each section. 24-item two-tiered test and 5 open ended questions were given as pretest and posttest. The open ended questions assessed students' problem-solving skills and ability to communicate the algorithm used, mathematical reasoning and making connections by justifying the steps of their solution. Mathematics anxiety questionnaire adapted from Dales [7] with slight modification was also given to determine students' mathematics anxiety.

The study employed a mixed method of quantitative quasi-experimental control group and qualitative design. The quantitative part examined the effect of students' mathematical communication on their mathematics performance, mathematics anxiety. The extent of the significant difference on the performance of the two groups was tested using ANCOVA. In determining students' proficiency level, the K-12 descriptive level was adopted. The qualitative data employed the content analysis of students' answers on the second tier questions and on the written justifications and explanations of their processes in the open-ended problem and getting insights on how students perceived the use of mathematical communication as a teaching-learning process.

### 2.1. Developing Students' Mathematical Communication through Discourse

Students' oral communication in the experimental group were developed through mathematical discourse. The teacher presented first an open-ended problem, and then asked students a series of questions guiding and leading students to analyze and reflect their thoughts to show strategies to solve the given mathematical task. The teacher helped students to recall theories and previous lessons to connect the concept behind the problem. Students and teacher were communicating and exchanging ideas to make students internalize and understand the concept on their own. This was done to equipped students with the concepts and skills on the subject matter for the day. Then, students were given activity sheets with prompts for the day's lesson. The activity contained the problems and guide questions on how to solve the problem. In the activity, students were required to assemble into small groups of three or four members to have discourse to solve the problems. This was done to accommodate shy students who felt uncomfortable in presenting their ideas to the whole class. Small group discussion among students encouraged slow learners to open up. Communicating with peers appeared to make them feel comfortable because they were all students and so they had more freedom to express their thoughts. The teacher-researcher monitored the discourse by asking the group relevant and essential question pertaining to the topic. This was done to guide students' line of thinking and reasoning. Group reporting was required to encourage each group to present their outputs. Reporting allowed students to articulate how the group arrived at the answer which helped them improve their oral communication skills as well as to enhance their conceptual understanding.

### 2.2. Developing Students' Communication through Writing in Mathematics

To develop students' communication skills in writing, the worksheets were used. Each contained the *title* of the lesson, the *learning target* with the description of the skills that students should develop, *concept notes* which were also incorporated with illustrative *examples.* It also included *vocabulary* of key terms which students defined in their own word to help them understand the concepts. E*xercises* were also given which required students to show algorithm and open-ended questions which required them to write their step-by-step description on how to complete the solution. Students were also required to provide their justification and explanation of when, where, how and why they applied such theory and process. In addition, students were also asked to write their *reflection.* This was given for students to internalize what they learned from their classroom participation, behavior and quantity of work done during the lesson and to identify topics they did not understand and have found difficult. They were given opportunities to review their work and to assess themselves. The reflection provided more information about their progress and encouraged them to be responsible of their own learning.

## 3. Results and Discussions

The results of the analysis are shown in the following tables.

**Table 1. Mean, Standard Deviation and Descriptive Level of Students' Mathematical Achievement Score**

| | Experimental Group (n=94) | | Control Group (n=94) | |
|---|---|---|---|---|
| | Pretest | Posttest | Pretest | Posttest |
| Mean | 4.47 | 64.17 | 5.77 | 15.61 |
| SD | 2.90 | 24.60 | 2.30 | 10.31 |
| Descriptive Level | Beginning | Approaching Proficiency | Beginning | Beginning |

Table 1 shows that students in the control group remained at the beginning level which means that there mean percentage score was below 30% of the total score, indicating that there was only little improvement and did not reach mastery level. Meanwhile, the students in the experimental group have improved from beginning level to approaching proficiency level in the posttest. The students' mean percentage score increased from 30% to 75% of the total score, which is the national standard criterion set by Department of Education. This means that students' achievement level had improved.

**Table 2. One-way ANCOVA Summary for Students' Achievement Score**

| Source | DF | Adj SS | MS | F | P |
|---|---|---|---|---|---|
| Treatment Within | 1 | 4558.0 | 4556.0 | 81.79 | 0.001* |
| Error | 186 | 10365.8 | 55.7 | | |
| Total | 187 | 14923.7 | | | |

*Significant at 0.05 level.

Table 2 shows the analysis of covariance of pretest and posttest scores of the experimental and control groups. The analysis yielded a computed probability-value lesser than 0.05 level of significance. This led the researcher to reject the null hypothesis. This implies that there is a significant difference in the students' mathematics performance in favor of the experimental group, which means that the experimental group exposed to communication process of learning performed better than those exposed in the DLP approach.

Content analysis of the students' answers on the two-tiered test questions also shows that students had improved in terms of achievement score and showed a good grasp of the concept as shown in their answers in the second-tier questions. Students gave varied justifications of their answer, which evidently showed that they were more able to make connections and had applied previous concepts learned.

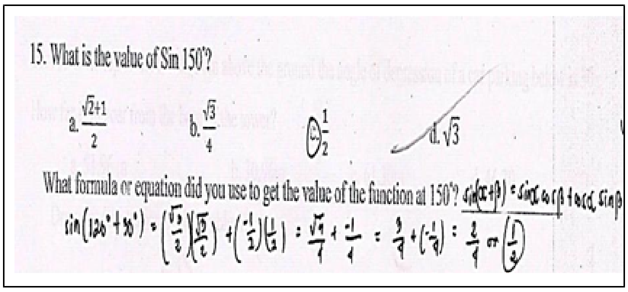


**Figure 1.** Answer on item number 15 written by a student from the experimental group (ES2) using sine of the sum of two angles formula

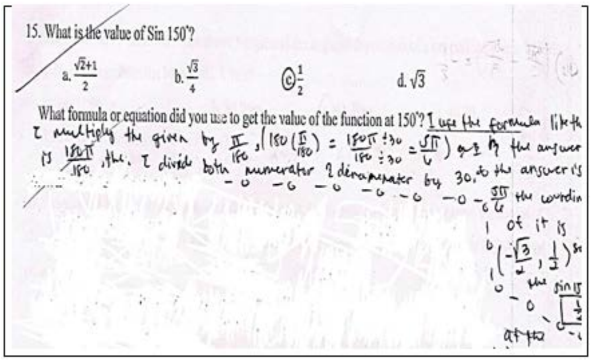


**Figure 2.** Answer on item number 15 written by a student from experimental group (ES3) using co-terminal angles to determine the value of the function

[Table 3](#) reveals that students in the control group showed improvement, from beginning level to developing level, this means that students' mean percentage score increased from below 30% of the total score to 70% in the post test, indicating that students in the control group had gained conceptual understanding after they were exposed to DLP method but on superficial level only. However, a greater improvement can be observed from the students exposed to mathematical communication. They had improved from beginning level to moderately strong level of conceptual understanding, with mean percentage score of 88%, indicating that they had satisfactory grasp of understanding of facts and theories in their class discussion.

**Table 3. Mean Scores, Standard Deviation and Descriptive Level of Students' Conceptual Understanding**

| | Experimental group (n=94) | | Control group (n=94) | |
|---|---|---|---|---|
| | Pretest | Posttest | Pretest | Posttest |
| Mean | 0.68 | 36.43 | 0.38 | 19.45 |
| SD | 1.53 | 13.03 | 0.95 | 10.88 |
| Descriptive Level | Beginning | Moderately Strong | Beginning | Developing |

**Table 4. One-way ANCOVA Summary for Students' Conceptual Understanding in Plane Trigonometry**

| Source | DF | Adj SS | MS | F | P |
|---|---|---|---|---|---|
| Treatment within | 1 | 17081 | 17081 | 286.29 | 0.001* |
| Error | 186 | 11097 | 60 | | |
| Total | 187 | 28178 | | | |

*Significant at 0.05 level.

[Table 4](#) shows the analysis of covariance of pretest and posttest scores for students' conceptual understanding. The analysis yielded a computed probability-value which is lesser than the 0.05 level of significance which led to the none acceptance of the hypothesis. This means that there is a significant difference in the students' conceptual understanding between the experimental and control groups. This implies that the conceptual understanding of students exposed to mathematical communication approach is significantly higher than those exposed to the DLP approach. This further implies that when students were allowed to communicate their ideas during class discourse and in writing, the process can led to improve their conceptual understanding that contributed to their higher mathematics performance.

The content analysis on students' answers in the open-ended problems further shows that students in the experimental group clearly acquired better understanding of the concepts discussed. Their answers clearly presented a correct interpretation of the problem, gave sufficient explanation to their answers by making connections and applications.

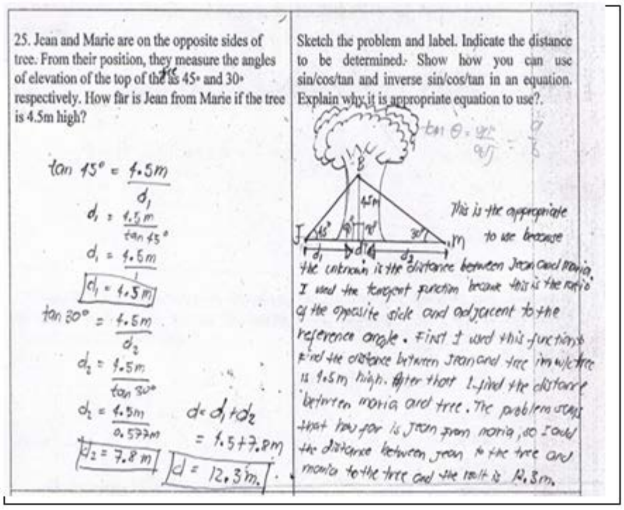


**Figure 3.** Answer of item number 25 written by a student from experimental group (ES10)

**Table 5. Pretest and Posttest Mean Scores, Standard Deviation and Descriptive Level of Students' Mathematical Anxiety**

| | Experimental group (n=94) | | Control group (n=94) | |
|---|---|---|---|---|
| | Pretest | Posttest | Pretest | Posttest |
| Mean | 2.73 | 2.28 | 2.78 | 3.27 |
| SD | 0.54 | 0.61 | 0.64 | 0.72 |
| Descriptive Level | Undecided | Disagree (Less Anxious) | Undecided | Undecided |

[Table 5](#) shows that the posttest mean score of the control group increases but it is still within the undecided level, they were not sure of their feelings towards mathematics. Meanwhile, the experimental group's mean shows that the students felt less anxious after the treatment. This indicates that promoting communication in the class had contributed to the reduction of the students' mathematical anxiety.

**Table 6. One-way ANCOVA Summary for Students' Mathematical Anxiety**

| Source | DF | Adj SS | MS | F | P |
|---|---|---|---|---|---|
| Treatment Within | 1 | 4.34 | 4.34 | 9.44 | 0.002* |
| Error | 185 | 85.07 | 0.46 | | |
| Total | 186 | 89.41 | | | |

*Significant at 0.05 level.

Table 6 shows that the computed probability value is lesser than the 0.05 level of significance. Thus, the null hypothesis is rejected which means that there is a significant difference between the mathematics anxiety of the experimental group and control group. The students exposed to communication process had significantly reduced their mathematics anxiety compared to the control group, indicating that allowing students to communicate their thinking and understanding of concepts in class could lessen their anxiety towards the subject. This could be due to the fact that mathematical communication through writing could give opportunities for students who were uncomfortable in oral situations to express understanding in class.

Students had positively agreed that mathematical communication was useful to them. 33.4% of the participants from the experimental group strongly agreed and 51.4% agreed that the process had helped them improved their achievement and reduced mathematics anxiety. 66% of the respondents admitted that they had difficulty understanding mathematical concepts, but being forced to write and to describe how they arrived at the answer, helped them understand the concept better. 49% found writing justifications and explaining their solutions to be interesting and thought provoking, 33% strongly agreed and 57% agreed that writing in mathematics helped them give more attention to accuracy and neatness of solution on their problem sets. Students' also responded positively on mathematics communication through group discourse who found that the process made mathematics enjoyable and fun (76%).

## 4. Conclusions and Recommendations

Based on the findings of the study, the researcher concludes that mathematical communication in mathematics class is an effective teaching method to improve achievement and conceptual understanding, and reduce mathematics anxiety. Hence, the researcher recommends the use of mathematical communication as a teaching strategy. Similar studies may be conducted to wider scope using different population to promote the generalizability of the results.

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