4S LEARNING MODEL: DOES THIS ENHANCE STUDENTS' MATHEMATICS COMMUNICATION?

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Abstract: *The study was quasi-experimental research conducted to investigate the effects of the 4S Learning Cycle Model on students' mathematical communication skills in terms of students' cognitive facets of understanding. The participants of the study were the two intact classes of freshmen education students in College and Advanced Algebra courses enrolled at the University of Science and Technology of Southern Philippines. One section was assigned as a control group that was exposed to Polya's Problem Solving Model while the other one was an experimental group that was exposed to 4S (Sense-Making, Showing Representation, Solving with Explanation, and Synthesizing) Learning Model. It used 8 open-ended questions to determine students' cognitive facets of understanding mathematics. The performance of the students was measured using their test scores. To determine if the 4S Learning Model significantly affects the mathematical communication of students, the Analysis of Covariance (ANCOVA) was utilized at a 0.05 level of significance. Results of the analysis revealed that the students exposed to 4S Learning Cycle Model have significantly higher mathematics cognitive facets of understanding compared to students exposed to Polya's Problem-Solving Model. Based on these findings, it can be concluded that the 4S Learning Cycle Model is effective in enhancing students' cognitive facets of understanding.*

Keywords*: 4S learning model, mathematical communication skills, sense-making, representation, synthesizing, cognitive facets of understanding*

1. INTRODUCTION

Effective communication plays a fundamental part in all facets of interactions, be it in the workplace, in social exchanges, or in the educational process. In class, communication is an act of conveying information between individuals, between the teacher and the students, or from one student to another student, creating in the process a shared understanding. This communication and how that interaction is shared determines what is learned and what is not learned in the classroom [1]. However, in mathematics class, communication in either oral or written is not easy because learning mathematics is learning a new language. Mathematics is unique with its combination of words and symbols and compact style [2, 3]. Understanding mathematics requires key skills in the use and interpretation of numbers, symbols, pictures, graphs, and dense texts.

Mathematics communication is a central force for students in formulating mathematical concepts and strategies [4]. This is when students can express their ideas, describe, and discuss mathematical concepts coherently and clearly [5], and can explain and justify action in procedure and process both orally and in writing [6]. Hence, it is a fundamental ability that must be acquired by all students to improve their thinking ability in mathematics lessons.

The most recent Program for International Student Assessment (PISA) findings, however, revealed a concerning fact regarding the performance of Filipino pupils in these mathematical abilities. Out of 77 participating countries, the average mathematics, science, and reading scores of Filipino pupils placed 76th, 77th in both science and reading and 76th altogether [7]. The assessment was specifically designed to measure the seven fundamental mathematical capabilities emphasizing students' mathematics communication.

In this context, mathematical communication skills should be improved since it may influence students' mastery in comprehending the given material, capturing the information needed, expressing their comments, and helping them see a new connection to clarify their thoughts [8]. According to [9] if the students are given opportunities to acquire a high level of mathematical communication, they may improve their mathematics performance since part of their success is dependent upon their ability to communicate their understanding of ideas.

However, teaching ways of communicating mathematically demands skillful work on the part of the teacher [10]. The teacher has a big role to play in developing mathematical communication in class [11]. Based on personal observation as a cooperating- teacher to pre-service teachers, mathematics teacher education students mostly found it difficult to express and communicate concepts in class. Hence, in the teacher education program, there is a need to develop the pre-service teachers' foundation skills both in content and pedagogy, as well as, in communication ability. Building a strong foundation on concepts in mathematics and problem-solving is essential for future mathematics teachers in terms of effectiveness and efficiency; although, it depends greatly on the teacher's capability and quality [12]. Thus, teacher education students need to be taught how to articulate sound mathematical explanations and how to justify their solutions. To be effective teachers, they should be encouraged to use oral, written, and concrete representations so that they will be able to model the process of explaining and justifying and guide their students into mathematical fluency and flexibility [13]. However, it is not clear why, thus far, current research in mathematics communication was conducted mostly among elementary or secondary students, and seldom explored among the tertiary students preparing to be mathematics teachers.

In designing mathematical tasks, a teacher should assure that it aims to improve students' mathematical communication skills by giving students opportunities for making sense of and process their understanding by showing representations of the tasks at hand. Moreover, giving time for students to formulate their solutions and explain how they arrive at their answers will also enhance students' mathematics understanding [5]. On the other hand, synthesizing one's process is giving students multiple opportunities to gain a better understanding of the concepts [14]. The NCTM standards implicitly invite researchers to articulate models of effective mathematical communication to improve their mathematical understanding of the concept [9]. Hence, this study aimed to explore the application of the 4S (Sense-

Making, Showing Representations, Solving with Explanation, and Synthesizing) Learning Cycle Model [3, 15] in mathematics to enhance students' mathematics communication. 4S Learning Cycle Model may change the paradigm of learning, from the old paradigm where the teacher is the center of learning, into a new paradigm in which students become the center of learning, and the teacher is a motivator and facilitator.

2. CONCEPTUAL FRAMEWORK

This study anchored on 4S *(Sense-Making, Showing Representations, Solving with Explanation, and Synthesizing)* Learning Cycle Model 4S of [3]; [15].

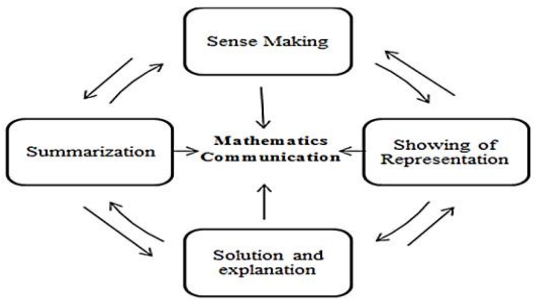


Figure 1. 4S Learning Cycle Model

Generally, 4S is grounded on the constructivist learning theory of [16] which states that learning is an active process in which students construct their knowledge and find the meaning of something they learned. In this 4S Learning Cycle Model, the teachers act as facilitators, helping students to construct their knowledge through an activity following the four components-cycle, sense-making, showing representations, solving with explanation, and synthesizing. This four-component learning cycle was also in accordance with the [17] principles and process standards for mathematics which promote problem-solving, logic and reasoning, representation, communication, and connection in teaching because they believed that if these processes were all used in the classrooms, these would develop the students' mathematics performance. The learning activities were designed to apply discovery learning through inquiry-based, where students were given problem situations from which they drew on their own experience and existing knowledge to discover facts and relationships and new truths to be learned [18]. Through the 4S components cycle, students were allowed to communicate mathematically by letting them interact with the world through exploring and manipulating objects, posing thought-provoking questions and controversies with their peers, and performing experiments. As a result, students would be more likely to remember the concepts and new ideas discovered on their own.

This study was also founded on the [19] sense-making model. Sense-making often involves gathering information, gaining an understanding of the information, and then using the understanding to finish a task that exhibits acceptable meaning of life [20] Further, [20] added that sense-making can effectively occur at various levels of aggregation (individuals, small/large groups and even communities), which often involving collaboration and student-student interactions. External resources could also be maximized during sense-making operations through the use of representations, be it by drawing diagrams or the use of visual, digital, and tangible manipulatives that could help students in the decoding and encoding of information to answer the given problem tasks.

Moreover, sense-making involves turning circumstances into a situation that is comprehended explicitly in words and could serve as a springboard into action [21]. However, Weick theorized that sense-making is a social psychology approach that involves the placement of stimuli into frameworks. These frameworks could be categorizations, anticipations, or assumptions. He further suggested that the recipe for effective sense-making is centered on employing student-student interactions through tighter social connections and active communication channels for arguing, negotiation, and updating.

Another component of the 4S Learning Cycle Model is showing meaningful representation. There are different ways of representing the same mathematical idea. For example, a relationship between two changing quantities may be verbally described or shown using diagrams, tables, graphs, and equations. Students should see the connections among equivalent representations of the same ideas [17, 22] proposed representation as one of the aspects of mathematical communication. The representation can help students to explain concepts or ideas and enables them to get problem-solving strategies. Moreover, it can increase flexibility in answering mathematics problems.

The third component of the 4S Learning Cycle Model is solving with explanation. The theory of conceptual fields [23] hypothesized that there are two forms of knowledge, the operational form of knowledge and the predicative form of knowledge. The former consists of action in the physical and social world, while the latter consists of the linguistic and symbolic expressions of this knowledge. In the solving with explanation part of the 4S Learning Cycle Model, Vergnaud averred that there is a need to establish better connections between the operational form of knowledge and the predicative form of knowledge if the goal of the third component is to be achieved. He further stressed that without words and symbols, representation and experience cannot be communicated; on top of that, thinking is often accompanied, or even driven, by linguistic and symbolic processes. As observed in the present study, when students were asked to write or pose their work on the board and explain it to the class, what they did most of the time was read what they had written. They did not explain the thinking that they used which enabled them to develop a solution or obtain the required answer. To enhance mathematical communication and thinking, teachers must require students to provide reasons for what they did and not just relate the procedures that they used to solve problems [17]. Qohar [24] mentioned that for students to be trained in mathematical communication skills, they need to get used to providing arguments for each answer and feedback on answers given by others so that what is being learned becomes more meaningful to them.

In addition, as [25] emphasized through their "Understanding by Design (UbD)" instructional framework the six facets of understanding, namely: explain, interpret, apply, perspective, empathize and self-knowledge is critical in fostering students' conceptual understanding. Hence, this present study adopted the three cognitive skills (interpret, explain, apply) and used these to gauge students' conceptual understanding.

Furthermore, writing in the context of mathematics assists in learning and retaining mathematical concepts. Essentially, writing in mathematics—like writing in all non-literary matters—is about communicating ideas with clarity and an appropriate level of detail to make these ideas understandable and traceable. The relationship between writing in mathematics and mathematical thinking, however, is intertwined and complex. Writing represents thought, which demands conscious awareness and intention on the part of the writer [26]). A student's writing renders his or her thinking more visible. When a student can express and explain her reasoning and justify her thought processes and solutions correctly in writing, it shows her command of the concept. As a student moves through the levels from an absence of understanding or, perhaps worse, misunderstanding, to mastery, he/she is aided by the process of writing and rewriting, and questioning and answering, wherein her conceptual understanding is established and embedded. Successive iterations of writing and revision lay down deeper layers of understanding through deliberation and analysis [27]

Finally, synthesizing can be used successfully in many ways in the mathematics classroom. It can increase understanding of concepts in students by giving them opportunities to see and think about the material in different contexts and discuss them with their peers. If students are struggling with a concept, their peers' explanations may be what they need to help them understand it and those explanations can come through summarizing. Synthesizing also makes understanding visible to teachers [14].

On the one hand, [28] has influenced the mathematics education community on how to develop conceptual understanding through problem-solving tasks. Polya aimed not to teach problem-solving for problem-solving sake only, but to help students learn to think the way mathematicians think when they do mathematics to strengthen conceptual understanding. Polya's four principles are to understand the problem, devise a plan, carry out the plan, and look back.

This study investigated the effect of the 4S Learning Cycle Model and Polya's Problem-Solving Model on students' mathematical communication skills, particularly, on understanding mathematics in terms of [25] three cognitive facets of understanding – to interpret, to explain, and apply, and reasoning. The schematic diagram below shows the relationship between the variables in the study.

Figure 2 shows the relationship of the independent variables which comprised the interventions such as the 4S learning cycle model with components: sense-making, showing representation, solving with explanation, and synthesizing, and Polya's problem-solving model. The 4S learning cycle model was employed in the experimental group while Polya's problem-solving model in the control group. The types of problem-solving instruction may cause an effect on the dependent variables which are the mathematical communication skills composed of the student's cognitive facets of understanding mathematics (interpret, explain, apply). The pre-test determined the students' pre-requisite knowledge and was treated as a covariate.

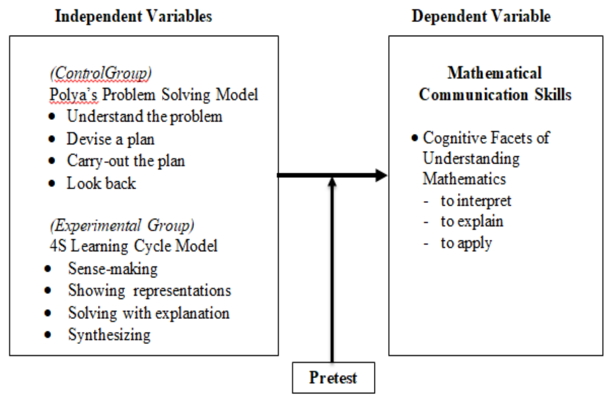


Figure 2. Schematic diagram of the interplay of the variables of the study.

3. MATERIAL AND METHODS

This study used a quasi-experimental research design. The participants of the study were the two sections in College and Advanced Algebra class who were first-year college students enrolled in this university taking up a Bachelor of Secondary Education major in Mathematics during the first semester, SY 2019-2020. One intact class with 38 students was randomly assigned as the experimental group and the other intact class with 38 students was assigned as the control group. The instrument was a teacher-made test to measure students' mathematical communication in terms of the cognitive facets of understanding, particularly their ability to interpret, explain, and apply. A table of specifications was also prepared. This test consisted of eight open-ended questions that covered topics in Linear Equations, Quadratic Equations, System of Linear Equations in Two Variables, and Linear Inequality. The time allotted for this instrument was one hour and thirty minutes. This instrument was validated with a reliability coefficient of 0.846.

4. RESULTS AND DISCUSSION

Table 1 illustrates the mean and standard deviation between the group's cognitive facets of understanding scores.

Table 1. Mean Scores and Standard Deviation of Students' Cognitive Facets of Understanding

	Control Group n=35		Experimental Group n=38	
	Pre-test	Posttest	Pre-test	Posttest
Mean	10.929	36.586	12.355	50.158
SD	8.316	17.693	9.504	20.019

Table 1 shows the pretest and posttest mean and standard deviation of students' cognitive facets of understanding Linear Equations, Quadratic Equations, Systems of Linear Equations, and Linear Inequality. It is observed that the students in both groups have low scores in their pretest. This result implies that both groups had equivalent standing before the treatment was administered. In the post-test, it can be noticed that the students in both groups have increased their mean scores. The control group has 39.586 and the experimental group has 50.158. It can be observed further that there is a difference of 13.572 in favor of the experimental group. The results reveal that both groups have manifested improvement, however, it is noticeable that the experimental group has improved more in cognitive facets of understanding compared to the control group. This indicates that the 4S Learning Cycle Model is a teaching strategy that could improve the students' cognitive facets of understanding.

The table also shows the standard deviations in the pretest of both groups. It can be noticed that the standard deviation of each group is high with the respective mean of each group. This means that the scores of the students of both groups in the pretests were heterogeneous. Some students got low scores in the pretest while some got very low. The standard deviations in the posttest are still high which means that their scores were still heterogeneous, some students got high scores while others got low scores. However, in the posttest, the group exposed to Polya's Problem Solving Model has a lower standard deviation than the experimental group who were taught with 4S Learning Cycle Model. The student's scores in the control group are more closely located to the mean. To verify whether the difference was significant, ANCOVA was further used.

Table 2. One–way ANCOVA Summary for Students' Cognitive Facets of Understanding

Source	SS	df	MS	F	p-value
Adjusted Mean	2429.6	1	2429.6	111.78	0.001*
Adjusted Error	14431.38	70	206.16		
Adjusted Total	16860.97	71			

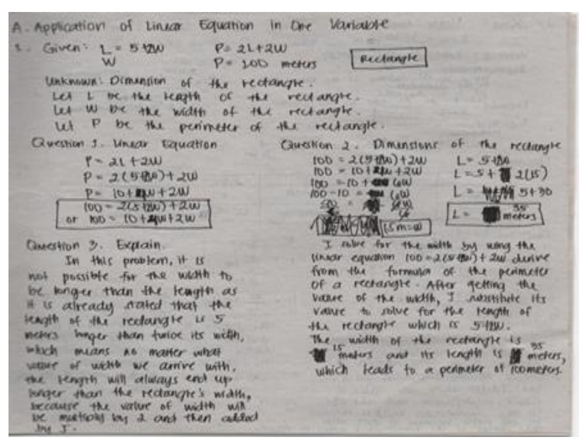
*significant at 0.05 level

Table 2 shows the summary of the analysis of the covariance of pretest and post-test scores for students' cognitive facets of understanding of the experimental and control groups. The analysis yielded a computed probability value of 0.001 which is lesser than the 0.05 level of significance. This led to the non-acceptance of the null hypothesis. This means that there is sufficient evidence to conclude that the cognitive facets of understanding of the students exposed to the 4S Learning Cycle Model are significantly higher than those exposed to Polya's Problem-Solving Model. This is because when the students were exposed to 4S (sense-making, showing representation, solving with explanation, and synthesizing) Learning Cycle Model, sense-making occurred in their mathematics classroom where they used their prior knowledge to develop an understanding of a new mathematical concept. They incorporated higher-level thinking questions in their group discussion and that led to an increase in their learning from procedural to conceptual understanding [29]. Students were allowed to utilize different types of representations to help them understand any mathematical word problem-solving [30]. They were given the chance to synthesize the concepts they learned in the given task and that helped them gain a better understanding of the concepts [14].

The content analysis of students' answers to the open-ended problems which measured their cognitive facets of understanding (to interpret, to explain, and to apply) showed that students in the experimental group clearly acquired a better understanding of the concepts discussed. As shown in Figure 3, the student from the experimental group answers are presented clearly and in a logical order, with a correct interpretation of the problem. They are able to translate the given conditions in the problem into a linear equation. They give a sufficient explanation to their answers by making connections and applications as shown in item number 1 (Figure 3). This problem required the students to show the appropriate linear equation to determine the dimension of the rectangle, a process needed to find out if they could interpret textual mathematical information into a complete, clear, and appropriate linear equation. The solution presented explicitly showed the correct interpretation of the problem through proper representation of the unknowns and showing the appropriate linear equation to determine the dimensions of the rectangle. It can also be observed that students are able to express their ideas by recalling the concepts of a plane figure and the perimeter of the rectangle. They are able to justify why they used the formula of the perimeter to find the dimensions of the rectangle. This implies that the students could explain and understand that the concept of the perimeter of a rectangle was needed to come up with a linear equation that was appropriate to find the dimensions of the rectangle. Another observation shows that students are able to apply previous concepts in Algebra and Geometry as shown in their mathematical process to solve for the length and width of the rectangle.

5. CONCLUSION AND RECOMMENDATIONS

Based on the findings of the study, it can be concluded that the 4S Learning Cycle Model is effective in enhancing students' cognitive facets of understanding. Teacher Education Institutions may adopt the teaching strategy, 4S Learning Cycle Model, to develop teachers with effective communication skills rich in content and pedagogy to produce competent teachers in Mathematics. The teachers in DepEd may also adapt this teaching strategy to improve the mathematical communication skills of their students.



1) The length of the rectangle is 5 meters longer than twice its width. The perimeter of the rectangle is 100 meters. What are the dimensions of the rectangle?

Question 1. Show the appropriate linear equation to determine the dimensions of the rectangle.

Question 2 What are the dimensions of the rectangle? Show your complete solution and explain how you arrive at your answer.

Question 3. Is it possible for the width of the rectangle to be longer than its length? Explain.

Figure 3. The answer to item number 1 was written by a student from the experimental group (EGS#11)

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