4S LEARNING CYCLE ON STUDENTS' REASONING SKILLS

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ABSTRACT: *This quasi-experimental study was conducted to investigate the effects of the 4S Learning Cycle Model on students' reasoning skills. The participants of the study were the two intact classes of freshmen education students in College and Advanced Algebra course enrolled during the 1st semester SY 2019-2020 at the University of Science and Technology of Southern Philippines. One section was assigned as a control group who was exposed to Polya's Method of Problem Solving while the other one was an experimental group who was exposed to 4S (Sense-Making, Showing Representation, Solution and Explanation, and Synthesizing) Learning Model. It used open-ended questions to determine students' reasoning skills. The questions were selected based on the cognitive demands and the content involved corresponding with the structure of the reasoning ability. The problem tasks were assessed according to three problem-solving skills: reproduction, connection, and reflection. The performance of the students was measured using their test scores. To determine if the 4S Learning Model significantly affects the reasoning skills of the 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 reasoning skills 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' reasoning skills.*

Keywords: 4S learning cycle model, reasoning skills, sense-making, representation, solving with explanation, ***synthesizing***

1. INTRODUCTION

Logical reasoning is of great societal importance and as stressed by the twenty-first-century skills framework [1]. The World Economic Forum (2020) actually reported that this is one of the top ten skills of tomorrow. This means that reasoning is one of the demand skills for future jobs. This is because reasoning is considered as a key aspect for the development of critical thinking and mathematical communication which are important skills to acquire for one to be able to solve complex problems in the field of work. People who reason and think analytically tend to note patterns, structure, or regularities, and investigate if those patterns are accidental or occur for a reason before they develop and evaluate arguments and proofs. This is one reason why since the early 2000 National Council of Teachers of Mathematics (NCTM) principles and standards had been promoting those mathematics in all levels should expose students in exploring phenomena, justifying results, and using mathematical conjectures in all content areas. In the Philippines, the reasoning is also one of the core competencies in the k to 12 mathematics curriculum [2].

Mathematical reasoning refers to the ability to formulate a given mathematical problem to explain and justify solutions or arguments. It is usually demonstrated during an advanced stage of thinking in the problem-solving process where students are expected to communicate either in written or orally their ideas to their reader or audience. Hence, reasoning as a mathematical communication ability is considered a marker of growth [3]. Others [3], further proposed that the search for the growth of reasoning in solving analytic problems should be characterized by the growth of mathematical communication abilities whose work is complete, correct, and sequential, especially in writing.

However, teachers commonly report experiencing difficulties in incorporating problem-solving and reasoning into their mathematics classrooms while at the same time catering to students with a wide range of prior experiences [4]. Often, instruction fails to help them find connections through reasoning and sense-making that may lead to a seemingly endless cycle of re-teaching. Engaging students in proving is a major challenge in school mathematics [5]. Despite its importance, it is infrequent in many mathematics classrooms because very few teachers and mathematics textbooks offer the opportunity for students to engage in conjecturing and proving problems [6].

Further, teachers found it challenging to integrate mathematical reasoning in their teaching. This is because the teacher should purposefully give attention and planning to hold all students in every mathematics classroom accountable for personally engaging in reasoning activities. A clear presentation of the problem tasks should be designed to help students in *sense-making* and leading them to the reason for themselves instead of merely observing and applying the reasoning of others [7]. Also, a careful selection and use of representations to facilitate students to the information given in the problem. By *showing representations*, teachers and students create a common space to carefully analyze and critique their thinking more concretely, constructing and revising their problem-solving processes together [8]. Moreover, giving time for students to formulate their solutions and *explain* how they arrive at their answers will also enhance students' mathematics understanding [9] and reasoning [3]. And finally, *synthesizing* activity supports the development of a profound understanding of complex material and to articulates one's understanding so that it can be shared with others. Hence, this study aimed to determine the effect of the 4S (*Sense-Making, Showing Representations, Solving with Explanation, and Synthesizing*) learning cycle on students' reasoning skills..

2. THEORETICAL FRAMEWORK AND REVIEW OF RELATED LITERATURE

This study is primarily anchored on the 4S Learning Cycle Model of [10]. 4S stands for *Sense-Making, Showing Representations, Solving with Explanation, and Synthesizing.*

Figure 1. 4S Learning Cycle Model

The cycle starts with sense-making in which others [11] describe as a process of searching for a representation and encoding data to answer task-specific questions. To be able to reason one should make sense of the problem by investigating and taking note of patterns, structure, or regularities and encoding these as an essential and the heart of understanding and problem-solving processes. The reasoning is the primary and continuous tool that one employs when trying to understand and solve problems in mathematics [12]. Hence, a careful and sequential process of questioning and investigations is necessary for one to make sense of and understand the given problem task.

The second component of the cycle is showing representation. This is credited to the constructivist concepts of intellectual development theory outlined from Piaget's propositions and Bruner's three modes of representations, the concrete, pictorial and abstract stages. The reasoning works when trying to understand the problem, making connections and representations between concepts in the problem to his previous knowledge, making conjectures and generalizations, and trying to prove conjectures made. Taking note of the patterns of irregularities found in the problem and relating these to concrete representation is the first stage in constructing representations. These may involve tangible manipulative with hands-on activities to be performed. Second, when images or visuals were made to represent concrete situations enacted through drawings, diagrams, and graphs, then the pictorial stage of representation took place. When all these images from the second stage were transformed into words and symbols, abstractions were formed, then students reached the symbolic stage of representation. The use of words and symbols allows the student to organize information in the mind by relating concepts together [10].

Solution and explanation is the third component of the 4S learning cycle model. When students were task to explain and justify their solution, and asked to summarize their understanding to foster their reasoning skills. Mathematics reasoning is explicitly stated as a proficiency to be developed in students and is defined as being the capacity for logical thought and actions, such as analyzing, proving, evaluating, explaining, inferring, justifying, and generalizing [13]. Mathematical reasoning in classrooms encouraged students to put forth their ideas for examination where teachers and students can questions, react, and elaborate. [14] believed that students need to explain and justify their thinking and learn how to detect fallacies and critique others' thinking. They need to have ample opportunity to apply their reasoning skills and justify their thinking in mathematical discussions and they will need time, many varied and rich experiences, and guidance to develop the ability to construct valid arguments and to evaluate the arguments of others [14].

For a good reason and proof to be appreciated, one should be able to communicate the main essence of the proof. Hence, when students were able to gather all the relevant points of the proof on the conjectures made and summarized it in a form of a generalization, then, the final component of the cycle has been reached.

3. METHODOLOGY

3.1 Research Design

The study used a quasi-experimental pretest-posttest control group design to examine the students' reasoning skills. The experimental group was exposed to treatment that utilized the 4S Learning Cycle Model while the control group was exposed to treatment that utilized the Polya Problem Solving Model.

3.2 Respondents of the Study

The respondents 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 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.

3.3 The Instruments

To measure the reasoning ability of the students, eight open-ended questions were constructed that covered topics in Linear Equations, Quadratic Equations, System of Linear Equations in Two Variables, and Linear Inequality. These open-ended questions were likened from the Programme for International Student Assessment [15] real-life problem-solving questions. The questions were selected based on the cognitive demands and the content involved corresponding with the structure of the reasoning ability. The problem tasks were assessed according to three problem-solving skills under the PISA framework: *reproduction, connection, and reflection* concerning mathematical explanations [16]. *Reproduction* skills refer to the application of routine algorithms and technical skills; the *connection* skills build on the standard problem-solving translation and interpretation, and the *reflection* skills include an element of insight on the solver's part. Besides, the questions were specifically chosen to solicit a qualitative analysis for correct arguments of explanations. This instrument was validated with a reliability coefficient of 0.913.

3.4 Rubric Scoring for Students' Reasoning Skills

Each item in the mathematical reasoning test was checked using the rubric adapted from the study of [12] modified to integrate the PISA framework of assessment [16]. The highest score in this test was 96. It has three criteria, namely: **reproduction skills** which refer to the application of routine algorithms and technical skills, **connection skills** that build on standard problem-solving translation and interpretation, and **reflection skills** which include an element of insight on the solver's part. Each criterion was given a maximum of four points. This open-ended questionnaire was rated by another mathematics teacher aside from the researcher to avoid bias in using the rubrics.

3.5 Data-Gathering Procedure

At the start of the class, a pretest was given to each participant in both groups to measure their reasoning skills. They were required to answer the test for one hour and thirty minutes. The experiment was conducted for 16 meetings and the duration of each meeting was one hour and thirty minutes. After 16 meetings of conducting the experiment and when all the topics were covered, a posttest was administered to both the experimental and control groups.

In the experimental group, the activity contained the four processes of sense-making, showing representation, solving with explanation, and synthesizing. In the first process, sense-making, each group read carefully and discussed among themselves how to solve the problem. The teacher prepared a short exercise for the students to answer which was incorporated in the activity sheet to review the students' prior knowledge and experiences to connect the concept behind the problem. Questions were also incorporated in the activity sheet for the students to discuss among themselves, after which they would answer the questions to develop their understanding of the situation and concept linked with the given problem.

The next process in this learning model was showing representation. The group did the brainstorming, students drew representations to visualize their understanding of the problem which helped strengthen their comprehension of the task at hand. These led them to translate the conditions in the problem to an equation in order to arrive at the correct answer.

After having the equation, the students discussed on how to find the solution set of this equation. The teacher-researcher monitored the discourse by asking the group relevant and essential questions pertaining to the topic. This was done to guide students' line of thinking and reasoning. The activity sheet contained also questions that required them to provide their justification and explanation as to why their equation was the appropriate one to find the solution set of the equation. They were also required to explain how they arrived at their answer. Answering these questions will help strengthen the students' reasoning skills.

The last process of this learning model was synthesizing. Each group was asked to present their solutions and synthesized the mathematical concepts they applied to solve the problem. This was an opportunity that provided the teacher with information about what the students knew and what they needed to learn.

The processes occurred cyclically. In an event that students failed to understand the required task in that specific process, they were advised to go back to the previous process or processes until they solved the given problem-solving task.

On the other hand, the control group was taught using Polya's problem-solving model. The first process was understanding the problem. To show an understanding of the problem, students read the problem carefully. Once the problem was read, students listed in the space provided all the components and data that were involved, draw the diagram, or illustrate if needed. They identified the unknown quantity. The second process was to devise a plan. Students translated the conditions in the problem into an equation. The members in a group discussed among themselves the strategy they would apply and devised a plan to solve the problem. The next process was carrying out the plan which means solving the problem. The students solved the problem. They discussed with their group mates how to solve the problem and they wrote on their activity sheet their solutions. The last process for Polya's problem-solving model was looking back. The students checked their solutions and tried to see if they used all the information and if their answers made sense.

3.6 Data Analysis

The performance in terms of reasoning skills of the students of both groups was described using the mean and standard deviation. The Analysis of Covariance (ANCOVA) was utilized to determine if there is a significant difference in the students' reasoning skills between the two groups subjected to the 4S Learning Cycle Model and Polya's Problem Solving Model. In testing the hypothesis, alpha was set at a 0.05 level of significance.

4. RESULTS AND DISCUSSIONS

Table 1. Mean Scores and Standard Deviation of Students' Reasoning Skills

	Control group n=35		Experimental Group n=38	
	Pre-test	Posttest	Pre-test	Posttest
Mean	9.186	30.271	10.434	44.474
SD	7.265	14.973	8.425	19.445

Table 1 shows the pretest and posttest mean and standard deviation of students' reasoning skills on Linear Equations, Quadratic Equations, Systems of Linear Equations, and Linear Inequality. It is observed that the control group gets a mean score of 9.186 out of 96 points while the experimental group gets 10.434 indicating that the reasoning skills of both groups are low. It means that the students in both groups before the start of the treatment had very low reasoning skills on Linear Equations, Quadratic Equations, Systems of Linear Equations, and Linear Inequality. In the posttest, both groups manifest improvement in their scores, but the experimental group gets the higher mean score of 44.474 while the control group gets 30.271. This means that the students in the experimental group had improved more in their reasoning skills than the students in the control group.

The table also shows the standard deviations in the pretest of both groups. It can be noticed that standard deviations are quite high already in both groups. This means that the scores of the students in the pretest were spread out. Some students got low scores in the pretest while some got very low. Considering the result of the posttest, the standard deviation of the control group which is 14.973 is smaller than the standard deviation of the experimental group which is 19.445. This means that the scores of the control group were closer to each other than that of the experimental group.

To verify whether the difference was significant, ANCOVA was further used.

Table 2. One–way ANCOVA Summary for Students' Reasoning Skills

Source	SS	df	MS	F	p-value
Adjusted Means	2767.63	1	2767.63	16.1	0.000*
Adjusted Error	12034.43	70	171.92		
Adjusted Total	14802.06	71			

*****significant at 0.05 level

Table 2 shows the summary of the analysis of the covariance of pretest and posttest scores for students' reasoning skills of the experimental and control groups. The analysis yielded a computed probability value of 0.000 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 reasoning skills of the students exposed to the 4S Learning Cycle Model are significantly higher than those exposed to Polya's Problem Solving Model. The result concurs with the study of [12] which said that when the students in a group discussed by making sense on the assigned task to understand the problem, the reasoning is triggered and in turn by reasoning, one improves his understanding. The process occurs cyclically. This shows reasoning is essential and at the heart of understanding and problem-solving process. [3] in his study also found out that the growth of geometric reasoning in solving analytic geometric problems is characterized by the growth of mathematical communication abilities whose work is complete, correct, and sequential, especially in writing.

2) A motorboat runs at the rate of 15 kilometers per hour in still water. It requires 3 hours to go upstream a distance which requires downstream in $1\frac{1}{2}$ hour. What is the rate of current?

Question 1. Construct a table that shows the condition of the problem.

Question 2. What is the rate of current? Show your correct and logical solution. Explain how you arrive at your answer.

Question 3. Why is it that the rate of the boat is slower when it runs upstream and faster when it runs downstream?

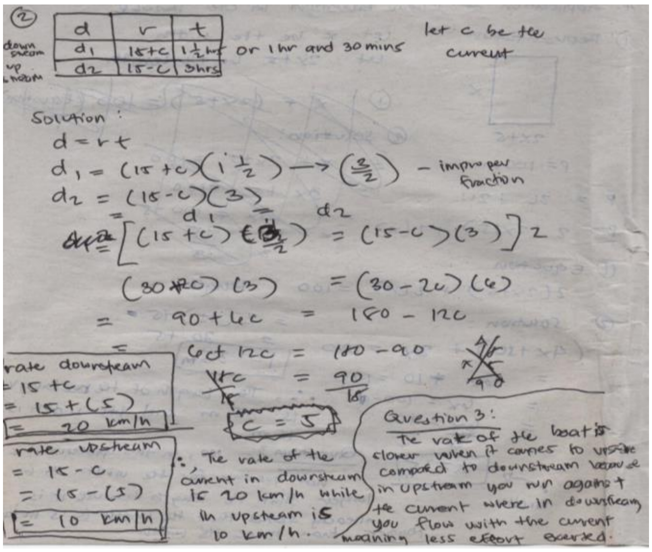

Figure 1. The answer to item number 2 was written by a student from the experimental group (EGS#23).

Figure 1 above shows the students' answers in the open-ended problems which measure their mathematical reasoning skills. It shows that students in the experimental group are able to develop or enhance their reasoning skills. The answers are presented clearly and they have completely examined the given information in the problem and have identified and demonstrated how to apply an appropriate model to address the problem. It is evident that students' skills on how to make connections were developed. Student number EGS#23 (Figure 1) has accurately carried out the computations and logical reasoning involved in solving the motion problem in item 2. He has correctly answered, explained well, and justified his solutions on the three questions in the problem-solving task where he is asked about the rate of the current and explains why the rate of the boat slows down when it runs upstream and becomes faster when it runs downstream. This implies that he had enhanced his reproductions skills and reflection skills. Mathematical reasoning is essential to bridging the gap between basic skills and higher-order thinking. In fact, the researcher has observed that students who are taught reasoning skills early on ultimately become more confident, independent learners; they have a deeper understanding of how a concept can be applied in a variety of situations and are willing to take risks to see what works and what does not. However, the student from the control group failed to completely examine the given information resulting in a wrong linear equation which is needed to solve the problem as illustrated in Figure 2 below. This implies that the student still needed to develop how to make connections and reflection on the concept discussed. It is evident that he has already acquired reproduction skills for he accurately carried out the computations, but since the linear equation is wrong so his final answer does not satisfy the conditions in the given problem-solving task. The students in the control group still needed to develop their reasoning skills so that they could answer easily and accurately the application problems.

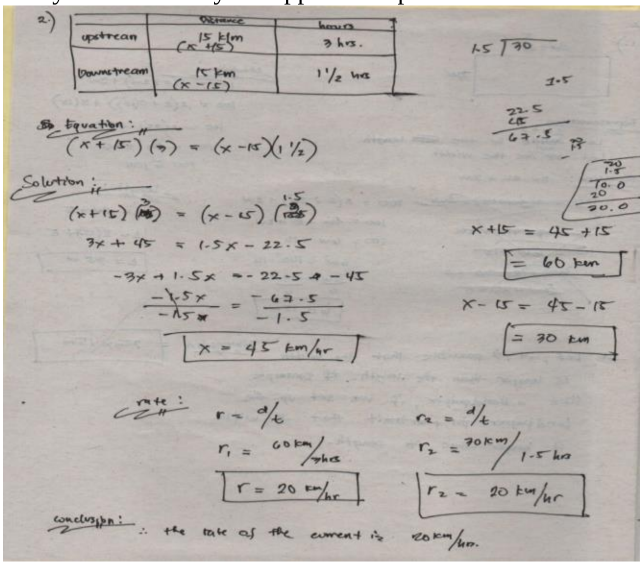

Figure 2. The answer of item number 2 written by a student from the control group (CGS#32)

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' reasoning skills. It is recommended that Teacher Education Institutions may adapt to the teaching strategy, 4S Learning Cycle Model, to develop teachers with advanced-level of reasoning skills to produce competent teachers in Mathematics. The teachers in DepEd may adapt this teaching strategy to improve the reasoning skills of their students. School principals and supervisors may support the implementation of the 4S Learning Cycle Model in the mathematics classroom to enhance students' reasoning skills.

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