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# SCHEMA- BROADENING INSTRUCTION IN GRADE 9 MATHEMATICS

**Jennylyn B. Bien**
*Graduate Student, Bicol University Graduate School, Legazpi City, Albay, Philippines*
*jennylyn.bien@bicol-u.edu.ph*

**Jayson A. Lucilo**
*Professor, Bicol University College of Science, Legazpi City, Albay, Philippines*
*jalucilo@bicol-u.edu.ph*

## Abstract

*This pre-experimental study is aimed to present the effects of using the Schema- Broadening Instruction (SBI) to the Mathematics performance of one Grade 9 class at a barangay high school in the Philippines. The study used a modified approach of SBI that adopted the use of the following visual and procedural schemes: (a) The Frayer Model; (b) Visual representations of variation equations; and (c) Polya's Four Steps in Problem Solving. The modified approach of SBI has also incorporated the use of structured (for concept formation) and open inquiry-based (for problem solving) activities. The approach aimed to reduce the students' cognitive load in learning Mathematics by introducing visual and procedural schemas. Schemas can be handled with very little conscious effort once acquired and automated. Hence, can reduce students' working memory load (Ericson, 2005). Results from the study showed that the students gained a wonderful experience of learning through the modified approach of Schema-Broadening Instruction. The students also showed capabilities of learning through structured forms of activities were guide questions and steps were provided for them in generalizing the concepts of the topic. But the Grade 9 students showed unreadiness for open inquiry-based activities and were not yet capable of constructing their own procedure in problem solving. The students preferred to be guided towards the step by step solution instead. Data gathered also showed that*

*the approach has improved the students' conceptual understanding that lead all the students to mastery. The students' performance under problem solving also showed improvements but was not enough for all the students to gain mastery. Future scope for the study would be to develop validated visual and procedural schemas that can further reduce cognitive overload in learning Mathematics.*

**Keywords**

Schema- Broadening Instruction, Visual Schemas, Procedural Schemas, Structured Activities, Conceptual Understanding, Cognitive Load

## 1. Introduction

The main approach used in the study is from a method of addressing students' difficulties in mathematical problem solving. This was done by introducing schemas used for solving specific types of word problems. Schemas are defined as outlines or plans in solving problems. They are considered as the building blocks of intelligent behavior, and is a way of organizing knowledge. Students, with the aid of schemas, are taught to recognize word-problem types and solve each problem type with specific schematic models and/or procedures (S. Powell, 2011). Such problem solution can be represented in pictures, diagrams, and equations that show the underlying structure of a problem. This approach is commonly known as the Schema-Broadening Instruction (SBI).

The study shows the effects of using a modified approach of SBI. This includes the use of schematic models namely: the Frayer Model- originally used in English to define a particular word but was used to visually summarize the properties of direct and inverse variation; and visual representations depicting the equations for direct, inverse, joint, and combined variations. Using these schemas, the students were provided with cognitive offloading tools in mastering the concept of variations. In addition, the visual representations were used as schematic tools during the process of problem solving. On the other hand, Polya's four steps in problem solving served as a guide for students in solving a problem.

Aside from this, the modified approach of SBI also includes the use of structured and open inquiry-based activity sheets in teaching concepts and problem solving. In structured inquiry-based activities, the students generalize the topic by answering questions and following some steps. In the context of problem solving. The students have different approaches and strategies that is according to their pace, skills, knowledge, and experiences. Hence, open inquiry-based activity sheets where used on lessons about problem solving, where students were given the opportunity to show and explore their own perspectives and approach of solving a problem.

The study was conducted at a barangay high school in Albay, Philippines. The school has a total population of 535 students and an average of 41 students in every class. Students in each class are heterogenous from Grade 7 to Senior High. Furthermore, the school has a small faculty size with 24 permanent teachers. Implementation period was during the 1st Quarter of S. Y. 2018-2019 and included 33 Grade-9 students with the discussion of the topic variations.

Mathematical modelling is defined as a process of applying mathematical concepts to new and unfamiliar situations (Nam, N. D., 2016). As such it is said that the goal of learning Mathematics is the development and deepening of mathematical concepts and relationship as students create, compare, and use various representations (Minarni, A., Napitupulu, E., & Husein, R., 2016). Studies involving visual representations have concluded that students' ability to represent mathematical concepts are highly dependent on their previously acquired knowledge that is with understanding and skills. It was then suggested for teachers to develop lesson plans that promote both skill development through modelling process practice.

According to the Cognitive Development Theory, learning is facilitated through interaction between peers (Law, Q. P., Chung, J. W., Leung, L. C., & Wong, T. K., 2017). This includes verbal discussion and observations of the students with their classmates or peers during the learning process. With collaboration, the typical teaching and learning process of being teacher- centered shifts to becoming student centered. This is because collaboration encourages students to be involved during the teaching and learning process. Furthermore, it was suggested that learning among the students can be greatly achieved through a structured learning environment.

According to Surif, J., Ibrahim, N. H., & Mokhtar, M. (2012), problem solving should be an experience from which students are learning freely. Be encouraged to investigate, seek for the truth, develop ideas, and explore the problem. From this experience, students can develop the courage to make decisions, act on that decision and be responsible for the outcome. Hence, shaping the students to be progressive, creative, ambitious. Thinking and rationalizing a solution plays an important role during problem solving. These skills require students to generate and develop systematic logical thinking. Wherein, they are required to first follow steps then determine the reasonableness of such approach in solving a problem. Thus, any successful attempt from modifying the approach encourages positive attitude towards solving a problem among the students (Alsubaie, M. A., 2016).

## 2. Research Issues

Existing studies presented on Schema-Broadening Instruction (SBI) were incorporated with direct explicit strategic approaches and visual aspects categorized according to problem type. These methods were proven by these studies as effective ways of improving Mathematical Problem Solving for primary and students with learning disabilities. None of the studies presented however have tried to further explore the effects of the approach to higher level of students and topic. Furthermore, these studies have not yet attempted to expand and modify the approach. Such that it can also improve students' conceptual understanding. Additionally, have focused in providing visual problem solution with no emphasis of allowing the students explore their own approach. Existing studies presented have also not yet used Polya's four steps in problem solving as basis for students to construct their own procedure in problem solving.

The study therefore aims to provide a new approach in context to schema-broadening instruction. A modified approach that does not focus on providing schematic solutions for word problems categorized into specific types. Rather an approach that will focus on providing a schematic model and visual representations in improving the students' conceptual understanding and problem solving. The modified approach also includes structured and open inquiry-based activities to promote independent and collaborative learning.

## 3. Methodology

The data collected was not only quantitative but also qualitative. The quantitative data was collected from the students' pre and posttest results while the qualitative data are from the students' journal entries, teachers' observation, and Focus Group Discussion with the students. There were two (2) main steps involved in conducting the study namely: (a) development of the research instruments: teacher-made test, lesson plans based from SBI with activity sheets, and journal questions; (b) implementation. The first step included the selection of the topic "Variations", from module 3 of the Grade 9 Mathematics learners' module. From this topic the test and lesson plans were constructed. Journal questions were used to monitor the students' significant experiences during the lessons. These materials were evaluated and edited accordingly before implementation. While the second step which was implementation was done during the 1st Quarter of S.Y. 2018-2019 for a span of three (3) weeks.

### 3.1 Instruments

The materials and instruments used for the study are the following (a) developed lesson plans with a modified approach of Schema- Broadening Instruction including the activity sheets. The lessons were evaluated by nine (9) Mathematics teachers from districts 1, 2, and 3 of the Albay province, Philippines. With an over-all weighted mean of 4.20, indicating that the lessons

and activity sheets developed were very satisfactory; (b) 50-item teacher-made test: was pilot tested and undergone item analysis with a reliability ¬(r) of 0.75. Interpreted to be a good test with a few items improved; (c) Evaluation sheet for the developed Lesson Plans, Journal Questions, and Focus Group Discussion Questions: these were all content validated by four (4) Master Teachers in Mathematics.

**3.2 Data Gathering Procedures**

A total of eight (8) lessons were conducted and were implemented for three (3) weeks. Each lesson involved an activity done by dividing the students into four groups. Before and after the implementation period, the researcher administered the pre- and posttest respectively. The raw scores of the students from the tests were tabulated, compared, analyzed, then statistically presented. The results were interpreted and discussed revealing the effects of using a modified approach of Schema-Broadening Instruction to the conceptual understanding and problem solving performance of the Grade 9 students. The students' significant experiences were collected and summarized from the students' journal entries and teachers' observation. Additionally, from the students' responses during the Focus Group Discussion and a brief interview with one of the observers.

**3.3 Statistical Treatment**

Weighted Mean. Used to generalize the overall rating of the evaluators for the teacher-made test and developed lesson plans; used to present the students' average pre and posttest scores before and after implementing the approach; and used in presenting the students' average performance during each activity.

Mean Gain. Used to determine if the approach gave a positive or negative difference between the pre and posttest mean scores. This shows weather or not the approach has positively or negatively affected the students' conceptual understanding and problem solving. The formula for this is:

$$\text{Mean Gain} = \text{Posttest mean score} - \text{Pretest mean score} \quad (1)$$

Performance Level. This is the percentage of the mean scores gained by the students. Simply computed from the quotient of the mean scores and the total number of items. The students' performance level before and after the approach was also presented and compared. Below is the table used for identifying the mastery level of the students before and after implementing the approach. Adopted from the DepEd Order no.8 series of 2015.

| **Performance Level** | **Mastery Level** |
|---|---|

| | |
|---|---|
| 92 and above | Full Mastery |
| 83% - 91% | Near Full Mastery |
| 75% - 82% | Mastery |
| 51% - 74% | Near Mastery |
| 25% - 50% | Low Mastery |
| 24% and below | No Mastery |

# 4. Results

## 4.1 Effects of Schema-Broadening Instruction in Grade 9 Mathematics

Conceptual Understanding. The students' conceptual understanding was developed through the structured inquiry-based activity sheets and the Frayer Model. Within the teacher-made test, 20 items were involved to measure the students' conceptual understanding.

**Table 1:** *Results of Students' Performance in Conceptual Understanding*

| Type of Variation | Pretest | | | | Posttest | | | | Mean Gain |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | s.d. | PL | | Mean | s.d. | PL | | |
| | | | % | $Q_1$ | | | % | $Q_2$ | |
| Direct (5) | 1.55 | 1.18 | 30 | $LM$ | 4.52 | 0.66 | 90 | $NFM$ | + 2.97 |
| Inverse (5) | 1.67 | 1.15 | 34 | $LM$ | 4.21 | 0.64 | 84 | $NFM$ | + 2.54 |
| Joint (5) | 1.09 | 0.87 | 22 | $NoM$ | 3.85 | 0.70 | 76 | $M$ | + 2.76 |
| Combined (5) | 1.30 | 1.06 | 26 | $LM$ | 3.70 | 0.87 | 74 | $NM$ | + 2.40 |
| Total (20) | 5.7 | 2.36 | 29 | $LM$ | 16.27 | 1.62 | 81 | $M$ | + 10.67 |

Legend: $\boldsymbol{PL}$- Performance Level
$\boldsymbol{Q_1}$ – Pretest Performance Level
$\boldsymbol{Q_2}$ – Posttest Performance Level
$\boldsymbol{NFM}$- Near Full Mastery
$\boldsymbol{M}$- Mastery
$\boldsymbol{LM}$- Low Mastery
$\boldsymbol{NoM}$- No Mastery

Results show that all of the students have shown improvement under conceptual understanding. This improvement had led them to gain mastery about the concept of variations. Specifically, the students from having "Low Mastery" were able to gain "Mastery". With reference to previous studies, the result under conceptual understanding was also evident to the students. Such that the students were able to use the schemes presented to naturally recall the information gained from the lessons.

To further support these findings under conceptual understanding, the activity sheets used for lessons regarding the concept of variation were assessed using the modified activity rubrics found in the Grade 9 Learner's Module.

**Table 2:** *Formative Assessment on Concept Formation*

| Criteria | Mean Scores | | | | Over-all Mean |
|---|---|---|---|---|---|
| | Direct | Inverse | Joint | Combined | |
| Clarity (5) | 4.0 | 4.5 | 4.5 | 4.8 | 4.5 |
| Accuracy (5) | 3.8 | 4.8 | 4.8 | 4.8 | 4.6 |
| Justification (5) | 4.0 | 4.3 | 4.3 | 4.3 | 4.2 |
| Time Frame (5) | 3.8 | 4.0 | 3.8 | 4.0 | 3.9 |
| Total (20) | 15.5 | 17.5 | 17.3 | 17.8 | 17.0 |

The table shows that the students have scored an average of 17 out of 20 or 85% performance level for the said activities. Indicating that the students performed well during the activities. Thus, supporting the students' posttest results under conceptual understanding. This also shows that the Grade 9 students are capable of learning under a structured inquiry approach.

Problem Solving. Under problem solving are processing skills namely: representing, reasoning, and computation. From the teacher-made test a total of 30 items assessed the students' performance in problem solving.

**Table 3:** *Results of Students' Performance in Problem Solving*

| Problem Solving | Pretest | | | Posttest | | | Mean Gain |
|---|---|---|---|---|---|---|---|
| | Mean | PL | | Mean | PL | | |
| | | % | $Q_1$ | | % | $Q_2$ | |
| Representing | 1.24 | 9 | $NoM$ | 8.67 | 62 | $NM$ | + 7.43 |
| Reasoning | 0.74 | 7 | $NoM$ | 5.88 | 59 | $NM$ | + 5.14 |
| Computation | 1.33 | 3 | $NoM$ | 14.94 | 31 | $LM$ | + 13.61 |
| Total | 3.52 | 5 | $NoM$ | 29.48 | 41 | $LM$ | + 25.96 |

Legend: $\boldsymbol{PL}$- Performance Level
$\boldsymbol{Q_1}$ – Pretest Performance Level
$\boldsymbol{Q_2}$ – Posttest Performance Level
$\boldsymbol{M}$- Mastery
$\boldsymbol{NM}$- Near Mastery
$\boldsymbol{LM}$- Low Mastery
$\boldsymbol{NoM}$- No Mastery

Based from the table, the students before the implementation period show no mastery of solving the four types of variation word problems. After implementing the approach, the students transitioned and showed near mastery for solving direct and inverse variation word problems. While under joint variation, the students showed low mastery and showed mastery for combined. The table also shows that the students' mean score was from 3.1 to 14.18 or a mean gain of +11.14 and 43% performance level (Low Mastery). Indicating that the students showed improvement in problem solving, but not enough for all to gain mastery. Although 30 or 91% of

the students showed improvements under problem solving, only one (1) showed "Full Mastery", four (4) showed "Near Mastery", and 25 showed "Low mastery".

The effects of the modified approach of Schema-Broadening Instruction under problem solving is consistent with the results of the related literatures presented (e.g., Jitendra, A. K., Star, J. R., Starosta, K., Leh, J. M., Sood, S., Caskie, G., ... & Mack, T. R., 2009). Showing, that the approach has improved the students' performance in problem solving, and benefits a range of students. But unlike existing studies on Schema- Broadening Instruction, the approach employed in the study does not involve fostering flexible solution strategies. Rather, provides visual representations for manipulating variables and solving variation equations. Then, allowing the students create their own procedure towards problem solving. Furthermore, according to the cognitive theory, students should learn to put mental effort in following and emulating examples and solving word problems (David, J., & Paulsen, R., 2017). Which in particular, the students failed to show in the study. This was because students preferred to be given guidance during problem solving instead of pursuing to take the challenge of relying on their own comprehension and problem solving strategy.

Nevertheless, results collected from the study shows that the modified approach in schema-broadening instruction can be a medium for improving the students' performance in problem solving. Likewise, the approach needs further development so that it can lead students towards mastery. Teachers should include fostering flexible problem-solving strategies and should encourage students put more mental effort and strategy in emulating examples and solving word problems.

Results from the study implies that with the modified approach in schema-broadening instruction, students' conceptual understanding and problem solving performance can be improved. Hence, indicates that the approach has shown a positive effect on the Grade 9 students' Mathematics performance. Additionally, results show that the approach is indeed applicable to diverse type of students. Supporting the claim of the study of Lim, 2015 that SBI is useful for all types of students. That is relevant to use for the present curriculum in the Philippines that systemizes heterogenous classes.

**4.2 Significant Experiences of the Students during Implementation**

The following are the students' significant experiences during the lessons developed: (1) the Grade 9 students gained a new experience and developed as independent learners; (2) the Grade 9 students found the topic variations easy to understand because of the schemes introduced; (3) the Grade 9 students enjoyed the activities that made them feel happy and excited; and (4) the Grade 9 students were able to gain knowledge from their classmates through

collaboration. Based from these significant experiences we can conclude that using the modified approach of Schema-Broadening Instruction, students can gain learning beyond the cognitive domain. Specifically, the students can develop as independent learners. Likewise, learn through collaboration. Additionally, gain enjoyment, excitement, and a new learning experience.

This implies that the approach used can also provide learning beyond the cognitive domain. Such that the students can improve as learners as well as experience a wider learning experience through the modified approach of Schema-Broadening Instruction.

## 5. Conclusion

Based from the data gathered, the approached used showed higher positive effect (in terms of performance level) on the Grade 9 students' performance under conceptual understanding than on problem solving. This improvement had led them to gain mastery about the concept of variations. Specifically, the students from having "Low Mastery" were able to gain "Mastery". With reference to previous studies, the result under conceptual understanding was also evident to the students. Such that the students were able to use the schemes presented to naturally recall the information gained from the lessons.

While based from the students' significant experiences, students can gain learning beyond the cognitive domain with the aid of the modified approach of schema- broadening instruction. Specifically, students can develop as independent learners. Likewise, learn through collaboration. Additionally, gain enjoyment and excitement in learning Mathematics. This implies that the approach used can also provide learning beyond the Mathematics competency being discussed. Such that the students are able to improve themselves as independent and active learners during class. As such it is said that the purpose of learning Mathematics is to develop as well as deepen understanding of mathematical concepts and relationship as they create, compare, and use various representations (Minarni, A., Napitupulu, E., & Husein, R., 2016).

### 5.1 Scope of Future Research

In accordance with the findings and conclusions drawn from the study, the following are recommended for future use and research: (1) Teachers can further improve the developed lessons using the modified approach of Schema-Broadening Instruction specifically for lessons on problem solving. (2) The approach can further be modified such that it can showcase more significant experiences among the students through collaboration and using other cognitive offloading tools. (3) Teachers should utilize and allow students develop various schemes during concept formation and problem solving. (4) In using Schema-Broadening Instruction, teachers should include structured inquiry-based types of activities. (5) In using Schema-Broadening

Instruction, teachers should provide flexible problem solving strategies for lessons on problem solving.

**5.2 Research Limitations**

The study exclusively focused on the effects of the modified approach of Schema-Broadening Instruction in the conceptual understanding, problem solving, and significant experiences of the Grade 9 students. Hence, fails to show the effects of the approach in terms of deeper cognitive domains involved in learning Mathematics. In view of the structured and open inquiry-based activity sheets the students' performance were also presented in the study. This provided information on the respondents' present ability and readiness to learn using structured and open inquiry-based activities. But fails to show on what areas the students needed improvement in order to achieve complete readiness for these types of activities. Furthermore, visual schemas used for the study were not validated and structured schemas that non-visual learners can also find useful in learning Mathematics.

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