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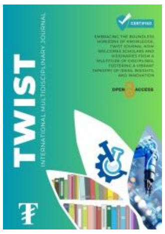

Advancing the Combinatorial Thinking of Grade 10 Students through Structure of Observed Learning Outcomes in Team Accelerated Instruction

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Abstract

This research analyzed how the structure of observed learning outcome (SOLO) in the cooperative learning Team Accelerated Instruction (TAI) affects the advancement of the students' combinatorial thinking (CT) Furthermore, this research determined the relationship of the advancement of CT and SOLO of grade 10 students. A 40 – student heterogenous class was selected as sample through cluster sampling. The respondents were exposed to the TAI treatment for 4 – weeks. Data were gathered through pretest and posttest in super – item format test. The data are then analyzed using the Wilcoxon Signed Rank Test and Spearman's rank correlation. The implementation of TAI significantly changed the students' CT (z=-5.593, p=0.000) and SOLO level (z=-5.638, p=0.000). This means that their performances have improved before and after the implementation of the TAI. Moreover, the advancement of students CT and SOLO level shows moderate significant correlation (r=0.549, $p < 0.05$). Based on the results of this research, Team Accelerated Instruction as a cooperative learning through the structure of observed learning outcome can help develop the students combinatorial thinking.

Keywords

Combinatorial Thinking, Cooperative Learning, SOLO Framework, Team Accelerated Instruction, Teaching Strategy, Mathematics

INTRODUCTION

Combinatorial thinking process is one of the thinking processes that an individual should develop. It is essential, especially in the mathematics thinking process. Hastusti, et al (2018) defined combinatorial thinking as a thinking process that provides the systematic steps in solving a problem. Hidayati, et al (2019) mentioned that combinatorial thinking is important in attaining the five learning process standards in Mathematics: representation, reasoning and proof, communication, connections and problem solving. Moreover, they emphasized its relevance to problem solving skills of the students.

The combinatorial thinking skills allow the students to solve problems, in different areas in Mathematics. The foundation of these skills is incorporated with the foundations of the Combinatorics in Mathematics, such as probability, computation, and enumeration of learning. Lockwood (2013) suggested the inclusion of combinatorics in the curriculum of mathematics education from primary to higher education. Combinatorics is included in the curriculum set by the Department of Education. It is the focus of the Grade 10 competencies for the third quarter, and it is also included on Grade 8 curriculum for the fourth quarter. Combinatorics is defined as the branch of Mathematics that is primarily concerned with the problems of selection, arrangement, and operation within a finite or discrete system. Its nature on solving problems make it an important competency to help the students become problem solvers.

Developing the higher – order thinking skills of the students has been the focus of the education system, not just in the Philippines but even internationally. This is evident with the Philippine Professional Standards for Teachers (PPST) issued by the Department of Education through DepEd Order no. 42, s. 2017. One of its indicators assesses the teachers' application of strategies in developing higher – order thinking skills. The development of higher – order thinking skills is expected to support the mastery of the 21st century competencies, namely critical thinking, creativity, communication, and collaboration (Scott, 2015).

In line with this, the DepEd BHROD issued an unnumbered memorandum dated May 26, 2023, known as the Conduct of Activities for the Higher – Order Thinking Skills Professional Learning Packages (HOTS – PLPs) for Science, Mathematics and English Teachers. This program aims to support teachers in understanding higher – order thinking skills by developing higher – order thinking skills items and questions for Science, Mathematics and English/ Reading subjects. In this regard, the Structure of Observed Learning Outcomes taxonomy was introduced to better categorized the students' higher – order thinking skills level.

The Structure of Observed Learning Outcomes (SOLO) taxonomy is a model that describes the levels of increasing complexity in students' thinking and understanding. As the thinking process progresses across the levels, the students move from factual knowledge to conceptual and abstract thinking and understanding. Hümbətova (2019) mentioned that the complexity of the SOLO level starts with the simple recalling to comprehension and leads to integration and abstract thinking.

Triana, et al. (2023) mentioned that the SOLO taxonomy is widely used to assess the learning outcomes through five levels of thinking, pre-structural, unistructural, multi-structural, relational and extend abstract. Where in the first level was identified as a no initial understanding level, and it goes with further in – depth knowledge as it increases the level of the taxonomy. Moreover, the SOLO taxonomy was developed to allow the teachers to develop rubrics, design learning experiences, and develop assessments.

The SOLO taxonomy framework designed as an evaluation tool for problem – solving is evident. Appulembang & Tamba (2021) mentioned that the students' ability to think critically as a basis of problem solving improves the student's cognitive thinking. Hastari, et. al, (2021) agreed that the SOLO framework can measure how the students think based on their level of thinking. Aside from it, the complexity of students' responses can also be assessed based on the framework. Sa'dijah, et al. (2021) mentioned higher – order thinking skills as a highly demanded skills in the 21st century. Tanujaya et al. (2017) acknowledge the importance of the higher order thinking skill in the educational process in Mathematics. In addition, the higher - order thinking skills shows a positive, linear, and strong relationship on the students' performance in Mathematics class. Higher – order thinking skills are important in learning Mathematics since it is focused on abstract ideas and its hierarchical concepts and deductive reasoning. This means that the materials or concepts encountered previously is related with the concepts on the next level.

According to Cardino, et al. (2020), teachers should use appropriate teaching strategies that best suit specific objectives and competencies to secure and make the transmission of knowledge easier. In addition, there is no single strategy that works for all types of learners. A traditional lecture may inspire some but frustrate others; a task-based approach may enthuse some but confuse and discourage others. As a result, teachers must carefully plan their lessons and employ a variety of teaching strategies to ensure that all students are satisfied (San Jose, 2015).

In connection, DepEd Order No. 42, s. 2017 underscored that one of the characteristics that quality teachers in the 21st century need to possess is "… mastery of content knowledge and its interconnectedness within and across curriculum areas, coupled with a sound and critical understanding of the application of theories and principles of teaching and learning so they can apply developmentally appropriate and meaningful pedagogy grounded on content knowledge and current research."

Nomsoor, et al. (2021) argued that on an almost daily basis, new instructional strategies are developed and implemented in classrooms, necessitating the need for teachers to be creative and employ a variety of them in the classroom. Effective instructional strategies are important because they provide a delivery mechanism for presenting content, give teachers the flexibility they need to meet individual needs, and make teaching and learning enjoyable. Meador (2018) further explained that most students learn best through active, engaging learning experiences.

Johnson and Johnson (2018) that the foundation of active learning is to allow the students to work together to maximize their own and each other's learning. This kind of learning allows the students to be an active participant in learning and allow them to experience learning through interacting with other individuals. They also mentioned that the foundation of active learning is cooperative learning.

One of the cooperative learning is in the form of Team Accelerated Instruction. Purnami, et al. (2018) suggested the great effect of using Team Accelerated Instruction in Mathematics since it allows the students to explore both team instruction and individualize activities. Using Team Accelerated Instruction because promotes not only active participation of students but also cooperation among the members of each group. The model also gives the teacher to minimize their involvement and strengthen student – student interaction through collaboration. In addition to this, using Team Accelerated Instruction also enhances the students' motivation in learning Mathematics because it makes the students be responsible on every individual and group discussion to be made to be able to have higher score in the assessment.

The researcher looked at the efficiency of team accelerated instruction in enhancing the students' combinatorial thinking skills through structure of observed learning outcomes model (SOLO model) assessment.

MATERIALS AND METHODS

In this study, the researcher used the quasi – experimental research design that involves data collection to determine the possible effect of adopting the structure of observed learning outcomes on the implementation of Team Accelerated Instruction in enhancing the students' combinatorial thinking. Moreover, the researcher used the pretest posttest design since the respondents of the research is an intact single group.

The data collection method involved the analysis of the scores of the participants in learning topics in Combinatorics particularly with Permutations and Combinations. The topics included illustration and identification of proper formula to use and problem solving.

The respondents of the study are 40 heterogenous Grade 10 students from Majayjay, Laguna which are selected through cluster sampling technique.

The study utilized research-made test to measure the combinatorial thinking level through the SOLO level based on a super – item test. The content of the test focused on the topics of permutation and combination which is part of the third quarter competency in Mathematics 10. The test is composed of one super – item test following the SOLO structure hierarchical arrangements of question. The item has a stem question with four leaf questions (starting from uni-structural level type question, multi-structural, relational and up to the extended abstract level of question). The students are instructed to answer each of the leaf problems by applying the four levels of combinatorial thinking. Mukuka, et al. (2020) gives the idea of measuring the structure of observed learning outcome level using super – item test. They further mentioned that the level of students could be measured depending on the highest level of problem that the students can answer correctly. To measure the combinatorial thinking level of the students, a rubric was used.

The implementation of team accelerated instruction started through administering the pretest (which corresponds to the placement test). With the results obtained with the pretest, the class is divided into groups with four members consisting of one low scorer, two average scorers and one high scorer. Each member of the groups cooperated for three weeks and achieved the team scores weekly through a fact test.

During the discussion, a problem is posed to the class and let each member of the group answer the problem individually based on their understanding of the problem. After it, the teacher instructed the students about the content or material to be used in the day. Then, the students went back to the posed problem and answered it based on the material discussed by the teacher. The students then are demanded to study and discuss the material and verify their answers along with the members of the group. They can discuss the process involved in answering the posed problem.

After the discussion among the group, another set of problems is given. In this phase, each member of the group is accountable for the progress of each other. They discussed the problems, solutions and verified their answers with the application of the different stages of combinatorial thinking. During this phase, the set of problems given to the students are based on the Structure of Observed Learning Outcome Level of questions. After the discussion, a representative of the group summarized and discussed the answers and the teacher assessed and evaluated the work of each group.

At the end of each week, induvial assessment was given to the students based on the topic discussed for the week. The score of each member of the group is added to get the score of the group. The group with the highest accumulated total score received a team reward.

After the implementation of Team Accelerated Instruction, a post test was given to the students. The posttest administered is a super-item format test. The students were assessed by first, in terms of structure of observed learning outcome level of the students based on the highest level of problem answered by the students; secondly, in terms of combinatorial thinking level students were assessed using a rubric.

For further analysis of the data, first, frequency and percentage were used to identify the SOLO level and combinatorial thinking of the respondents during the pretest and posttest before and after implementing the team accelerated instruction. Secondly is the Wilcoxon Signed Rank Test. It was used to determine the significant change on the scores between the pretest and posttest of the students to determine the significant change in the level of the students on combinatorial thinking and structure of observed learning outcomes. Lastly, Spearman Rank Correlation was used to determine the relationship between the advancement of the students' level on combinatorial thinking and structure of observed learning outcome.

RESULTS AND DISCUSSION

Pretest and Posttest Performance of the Respondents in Terms of the Structure of Observed Learning Outcomes

The level of the students' cognitive aspects in terms of the SOLO taxonomy is summarized in table 1. It has shown that during the pretest, most of the students are classified to be in the pre – structural level (25 out of 40 or 62.5%). This indicates that most of the respondents were not able to answer any of the problems and this is because they are new to the topics or concepts presented on the pretest. This clearly suggests that the students failed to interpret the information supplied by the problem and lack basic understanding of the combinatorial concepts. Putri, et al, (2017) described the characteristics of students in pre – structural level as they might give understanding on a problem but might have used irrelevant information or missed the point of the problem. They might show a little knowledge about a certain concept, but they are still unorganized, unstructured, and essentially void the actual content of a topic or a problem.

Table 1 Structure of observed learning outcome level of the students in the pretest and posttest

Level	Structure of Observed Learning Outcomes			
	Pretest Performance		Posttest Performance	
	Frequency	Percentage	Frequency	Percentage
Pre-structural	25	62.5%	-	-
Unistructural	14	35.0%	7	17.5%
Multi-structural	1	2.5%	18	45.0%
Relational	-	-	10	25.0%
Extended Abstract	-	-	5	12.5%
Total	**40**	**100.0%**	**40**	**100.0%**

Furthermore, during the posttest, the table shows that most of the respondents are classified to be under multi – structural level (18 out of 40 or 45%). This implies that most of the respondents, after Team Accelerated Instruction was used, were able to answer problems that involved two or more operations. In the case of the given posttest, the students are required to perform two combinations, the combination of 2 female from 4 elected female presidents and the other one is the combination of 2 male from the 2 elected male presidents.

STEM: Sta. Catalina Integrated National High School will create a new student council. The new student council will form a committee consists of 4 members to be chosen from 6 elected presidents of Grade 10 sections.

b. If the committee required to have 2 males and 2 females, how many ways can this be chosen if among the elected presidents 2 are male and 4 are female? (*Multi-structural*)

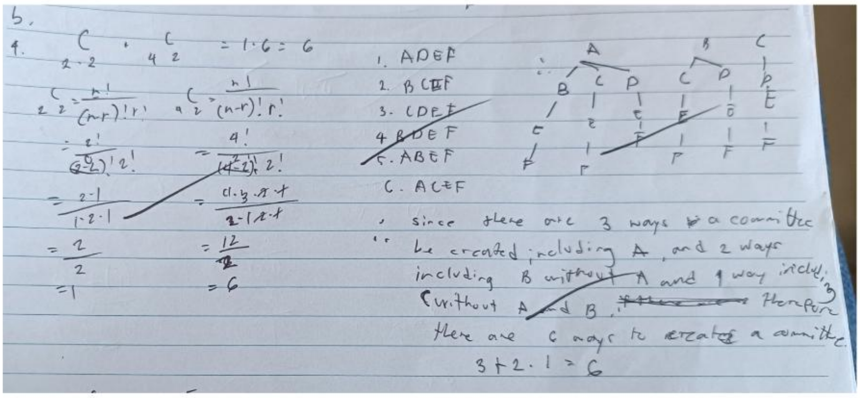

Fig. 1 Sample Response of the student in a multi – structural type of question

However, it is noticeable that there are students who reached relational (25%) and extended abstract (12.5%) level. This means that the use of the Team Accelerated Instruction somehow affects the performance of the students. Students at the relational level are expected to use one concept of Mathematics to another concept of Mathematics to be able to answer the given set of problems. Mukuka, et al, (2020) elaborate the characteristics of a student at the relational level. According to them, students in this level were able to generalize concepts and apply one concept to the other of the same field. Moreover, the students in the extended abstract showed a remarkable achievement of applying one concept from one field to another. Mukuka, et al, (2020) described students in this level as students that can apply existing or emerging structures into a new and more abstract situation.

Pretest and Posttest Performance of the Respondents in Terms of the Combinatorial Thinking

Presented on the table below is the students' performance during the pretest and posttest in terms of the combinatorial thinking before and after the implementation of the team accelerated instruction.

Table 2 Combinatorial thinking level of the students during the pretest and posttest

Level	Combinatorial Thinking			
	Pretest Performance		Posttest Performance	
	Frequency	Percentage	Frequency	Percentage
Unable to Answer	12	30.0%	-	-
Identifying	27	67.5%	-	-
Selecting	1	2.5%	15	37.5%
Concluding	-	-	21	52.5%
Reflecting	-	-	4	10.0%
Total	**40**	**100.0%**	**40**	**100.0%**

As shown on the table, twenty – seven out of forty (67.5%) of the respondents fall under the identifying level in terms of their combinatorial thinking. However, it is noticeable that nobody reached the reflecting and concluding level. The result revealed that most of the respondents showed understanding on the problems given and were able to list down possible sets that are included in the criterion mentioned in the problem. Hidayati, et al, (2019) describe the identification level where students can recognize problems in combinatorics. Students can identify an object as a question of the sets and list notation sets based on the problem criteria. The listing method is classified as the lowest level of combinatorial thinking since it is part of the identifying level. However, there are students that were able to answer the questions in relational level (leaf question c) applying the identifying level but failed to give the correct response.

On the other hand, during the posttest, 21 out of 40 (52.5%) respondents reached the concluding level of combinatorial thinking. Also, it is noticeable that no students remained in the identifying level. The lowest level obtained by the respondents is the selecting stage. This implies that after the Team Accelerated Instruction was utilized there is shown improvement in their performances. Most of the respondents draw conclusions based on the objects they have observed in the previous level. Hidayati, et al, (2019) emphasized the importance of the concluding stage as it is related to success in solving a problem.

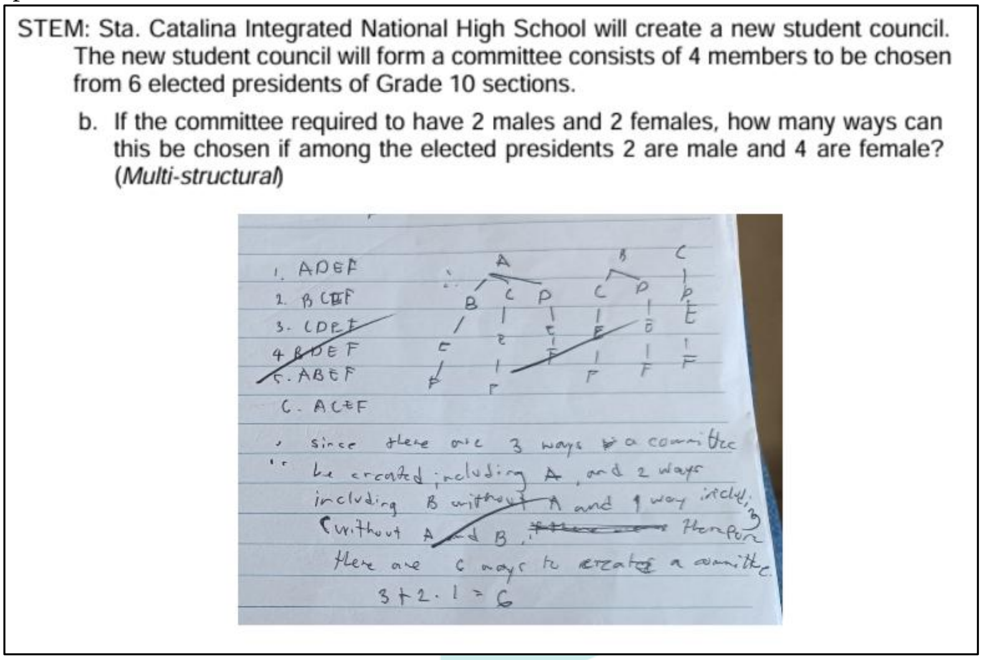

Fig. 2 Sample Conclusion constructed by the Students during the Posttest

Significant change on the Students SOLO and Combinatorial Thinking Level

The computation results are provided in table 3. The results showed p – value (0.000) for both the structure of observed learning outcomes and combinatorial thinking level. The results suggest that there is a significant difference on the students' SOLO level and combinatorial thinking level before and after the implementation of the team accelerated instruction.

Table 3 Test of difference through Wilcoxon Signed Rank Test on the pretest and posttest performances in terms of students' SOLO and combinatorial thinking level

	Structure of Observed Learning Outcomes (Pre-test and Posttest)	**Combinatorial Thinking (Pre-test and Posttest)**
Z	-5.638	-5.593
Asymp. Sig. (2 – tailed)	.000	.000

Ridwan et al. (2022) have mentioned the positive impact of cooperative learning on the enhancement of the students' mathematical learning outcomes by helping each other understand the learning materials. Students cooperate in small groups to help each other in understanding the material until they reach certain Structure of Observed Learning Outcomes Taxonomy level. Mukuka, et al, (2020) mentioned that cooperative learning increases the students' understanding of Mathematical concepts. As observed in the implementation of the team accelerated instruction, students became more accountable on their learning since their performance highly affects the performance of their group. The higher the level an individual reached in the test, the greater the points they will obtain. Mukuka (2020) further mentioned that through cooperative learning the students can take responsibility for their own learning and become actively involved in knowledge construction.

On the other hand, Simamora and Zunaiedy (2021) gave emphasis on the importance of cooperative learning in the advancement of students' Combinatorial thinking. They further mentioned Vygotsky's idea that the experience of the students when solving problems with their study groups with a socio – cultural approach improves their mental function higher. In Team Accelerated Instruction, students discuss with their groupmates. They have equal opportunity to succeed. Students explain to one another for them to learn and move on to the next learning task given. Moreover, when students organize their thoughts to explain their ideas and engage in cognitive skills, it increases their combinatorial thinking ability. As observed during the implementation of the team accelerated instruction, the students were free to discuss the different methods and solutions that they used in solving problems that involve permutation and combination. The top performing members of each group help the other members to make progress on how they solve specific problems during their discussion. In addition to this, the team rewards phase of the TAI also gives motivation to students to reach until the reflecting part so that their group gains more points and be recognized as the most performing group for the weekly assessment. Widodo, et al (2018) defined team rewards as giving scores on the results of group work and giving awards to groups that succeed in learning and obtain the highest score.

Correlation between the Advancement of SOLO and Combinatorial Thinking Level

The following table shows the degree of relationship between the advancement of the students' combinatorial thinking and structured of observed learning outcomes. The result is as follows.

Table 4 Test of relationship between the advancement of student's combinatorial thinking and SOLO level

	Combinatorial Thinking Advancement
Structure of Observed Learning Outcomes Advancement	.549**

**. Correlation is significant at the 0.01 level (2-tailed)

Based on Table 4, the combinatorial thinking advancement of the students has a significant relationship on their structure of observed learning outcomes advancement. This leads to the rejection of the null hypothesis.

The r – value 0.549 indicates that there is a moderate positive relationship between the two. This means that as the combinatorial thinking level advances, the structure of observed learning outcome level tends to advance also but not necessarily in a struct linear way. The strength of the relationship of the two indicates that there is still variability in the data points.

For instance, there are students that were able to proceed to reflecting level but fall under the second leaf question (multi – structural level). The performance of the students in comparing the relationship between the combinatorial thinking and structure of observed learning outcomes is not linear. However, their performance in the pretest and posttest both in development of combinatorial thinking while advancing the structure of observed learning outcomes is evident. The enhancement of combinatorial thinking is evident as the student progresses in the super – item test. This development is highly affected by the team accelerated instruction, especially through the individual accountability of the students.

It is also observed during the implementation of the team accelerated instruction allows the student to develop their thought processes through sharing their thoughts, insights and solutions among the members of the group. The sense of belongness of the students while asking verification of their answer among the group members and discussed what went wrong in their solution allows the student to have an equal opportunity to learn.

CONCLUSION

The researcher concluded that the use of team accelerated instruction helps in advancing the SOLO level and developing the combinatorial thinking of the students. In addition, the advancement of the students' SOLO level shows a moderately correlation with their combinatorial thinking advancement. Based on the researcher's findings and conclusion it is educators and educational practitioners are encouraged to use the team accelerated instruction should as classroom instruction to enhance performance in Mathematics specially in problem solving. Future researchers are also encouraged to conduct similar studies by expanding the topics of the combinatorics concept so that the research can analyse more the combinatorial thinking of the grade 10 students. Moreover, it is also encouraged for future researchers to conduct similar studies exploring how the structure of observed learning outcomes be adopted in different teaching and learning processes.

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DECLARATION OF CONFLICT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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