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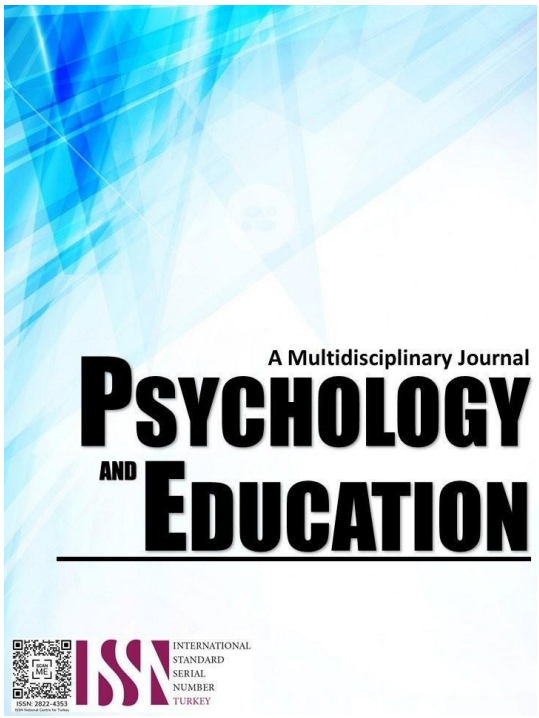

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Research Article

SOLO (Structure of Observed Learning Outcomes) Based Metacognitive Approach in Students' Creative Thinking and Science Literacy in Physics 8

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Abstract

Science literacy and creative thinking are key competencies emphasized in the Program for International Student Assessment, which evaluates students' ability to apply scientific knowledge to real-world problems and think critically and creatively in solving complex challenges. Thus, this study examines the impact of the Structure of the Observed Learning Outcome Based Metacognitive Approach (SOLO-BAMA) in improving students' Science Literacy and Creative Thinking. The SOLO framework, introduced by Biggs and Collis (1982), provides a hierarchical model for assessing student learning, emphasizing metacognitive development and deeper understanding which was in the content of Higher Order Thinking Skills Professional Learning Package (HOTS-PLP) introduced by the Department of Education. A true-experimental research design was employed, utilizing pretest and posttest assessments to measure learning gains among students exposed to SOLO-based instruction and those taught through traditional methods. The results indicated that students in the SOLO-based learning environment exhibited significantly greater improvements in both Science Literacy and Creative Thinking. Statistical analysis using the Mann-Whitney U test confirmed significant differences in posttest scores demonstrating the superior effectiveness of SOLO-based instruction. Additionally, the intervention group achieved higher learning gains than the control group, supporting previous findings that metacognitive strategies enhance student comprehension and problem-solving skills. These findings suggest that integrating the SOLO framework in science education fosters deeper learning, higher-order thinking, and conceptual understanding. The study recommends broader implementation of SOLO-based strategies and further research across diverse educational settings to assess its long-term impact.

Keywords: *creative thinking, SOLO, science literacy, student learning, HOTS-PLP*

Introduction

The Department of Education introduced the Higher Order Thinking Skills Professional Learning Package (HOTS-PLP) to enhance the teaching strategies that allow students to learn higher-order thinking skills and which parallel international assessments like PISA and the National Achievement Test to inform educational reforms. Covered by the Sulong Edukalidad initiative, the Philippines participated in the 2022 PISA cycle to enhance the quality of education. This study seeks to determine the effectiveness of Structure of Observed Learning Outcomes Based Metacognitive Approach (SOLO-BAMA) a learning material developed and implemented by the researcher to enhance the science literacy and creative thinking skills of students in physics.

In terms of science literacy and creative thinking, in particular, the PISA 2022 results draw attention to several global concerns surrounding science education (Teig et al., 2022). These include differences in scientific literacy and innovative problem-solving between nations and socioeconomic groupings, where children from lower-income backgrounds do worse than those from higher-income backgrounds (Butler, 2013).

In Asia, the Programme for International Student Assessment (PISA) is a pivotal function, underpinning the evaluation of performance of education on which policy initiatives are based (Ho & Gan, 2023). High-performing countries in PISA tests such as China, Japan, South Korea, Singapore, and Hong Kong can be ranked high in the PISA league tables which acts to highlight both strengths and weaknesses of their education systems (Tan, 2018).

The performance of the Philippines in the PISA 2018 assessment was below the international average in reading, math, and science Acido and Caballes (2024). The country ranked 78th out of the 79 countries or economies (Shmygol et al., 2020). Hence, this low academic standing essentially reflects the challenges that the Philippines has been battling within its education department for decades (San Juan, 2016).

According to Guiaselon et al. (2022), pupils' performance on the National Achievement Test in Science has not increased over the last ten years (NAT 2005-2015). The Grade 10 National Achievement Test results for Sultan Kudarat division revealed that pupils' critical thinking and problem-solving abilities had an MPS of 35.56% and 39.13%, respectively. As a result, the evaluations still need improvement. Sir Fontanilla, the superintendent of the Schools Division, encouraged all teachers and school administrators to take this seriously (Dy & Sumayao, 2023).

Hence, there is a gap in the development and availability of instructional materials for the Programme for International Student Assessment (PISA). Current materials often fail to address specific skills and real-world applications, such as critical thinking, problem-solving, and scientific literacy Orhan (2020). The lack of competency-based resources hinders student preparedness, especially in low-income regions where resources are often outdated. Additionally, teachers often lack access to PISA-oriented teaching guides or training, making it challenging to provide effective instruction (Johar et al., 2024). Educational performance improvement together with equity promotion

requires modern teaching resources which follow the PISA assessment model (Kyriakides et al., 2019).

DepEd Order No. 29 s. 2017 developed system assessment guidelines for PISA and similar tests which direct curriculum changes and policy choices in addition to developing instructional materials that fulfill international standards according to Lapinid et al. (2024). The document enforces extensive use of PISA outcomes to produce materials and programs which enhance student readiness for international tests (Rutkowski, 2015).

This research intends to develop instructional content that applies PISA and MELCS competencies based on HOTS-PLP of the Department of Education. SOLO taxonomy was used to the assessment of students' responses and outputs and Metacognitive Approach was utilized to assist students in PISA preparation for better results in creative thinking and science literacy education.

Research Questions

The main drive of the study is to determine the effect of SOLO-Based Metacognitive Approach to the scientific literacy and creative thinking skills of the Grade 8 students in Mamali National High School, Division of Sultan Kudarat. Specifically, this study sought to answer the following research questions:

1. What are the levels of students' performance in their pretest and post test score using:
    1.1. SOLO based metacognitive approach; and
    1.2. conventional approach?
2. Is there a significance difference between the students' pretest scores using the SOLO Based Metacognitive approach and the Conventional Approach?
3. Is there a significance difference between the students' post test scores using the SOLO Based Metacognitive approach and the Conventional Approach?
4. Is there a significant difference between the students' learning gains using SOLO Based Metacognitive Approach and Conventional Approach?

Methodology

Research Design

This research employed true experimental design to examine the effects of the Structure of Observed Learning Outcomes-Based Metacognitive Approach (SOLO-BAMA) on scientific literacy and creative thinking of Grade 8 students. A true experimental design is one of the most rigorous methods for establishing cause-and-effect relationships. In this design, participants are randomly assigned into treatment and control groups (Tanner et al., 2018). The treatment group receives the intervention (SOLO-BAMA), whereas the control group receives traditional teaching methods. Both groups are then took the pretest and post-test to compare the results before and after the implementation (Aitken et al., 2011)

Respondents

The respondents of the study are from Grade 8 Hestia and Artemis students of Mamali National High School, Mamali, Lambayong, Sultan Kudarat. These students were officially enrolled for the School Year 2024-2025. Three (3) regular section of Grade 8, they are grouped heterogeneously. There were 25 respondents from Grade 8 Hestia and 24 students from Grade 8 Artemis for the total of 49 respondents. Ballance (2024) state that the experimental procedures call for at least 15 individuals.

Table 1. *Distribution of Respondents*

Groups	*Male*	*Female*	*Total*
Controlled Group	12	12	24
Experimental Group	13	12	25

Source of data: Office of Registrar_Grade 8 S.Y.2024-2025

The researcher utilized complete enumeration sampling with this approach, information is gathered from every person in the population. It is used when a researcher wants to examine the whole population as opposed to a subgroup. It guarantees that no information is omitted, giving the people a thorough and accurate depiction. The researcher placed 3 pieces of paper labeled experimental, controlled group and one paper is blank. As part of study's methodology, each section had a representative to pick a paper which group they were assigned.

The lottery method ensures that all individuals in the population have an equal probability of selection Lopez-Guerra (2011). It is a way of minimizing selection bias, one of the major threats to validity Dunbar-Jacob (2012). When we select respondent on random base, we get sample which is highly representative and like the population Gile & Handcock (2010).

Instrument

The primary instrument used in this study was a developed Structure of Observed Learning Outcomes Based Metacognitive Approach (SOLO-BAMA) learning material to enhance the performance of the students in Science Literacy and Creative Thinking. The learning objectives of each lesson were based on the learning competencies of PISA and MELCS based on the Higher Order Thinking Skills – Professional Learning Packages (HOTS-PLPs) for Science, Mathematics and English Teachers reference for Grade 8 of Department of

Education which specifies on the use of metacognitive approach.

Furthermore, a Scientific Literacy and Creative thinking Two-Tier Test was also employed. It is an A 80- item Pre-test and Post test questionnaire that assessed students creative thinking and Scientific Literacy. The researcher prepared a rubric to ensure the proper scoring of the test. A Table of Specifications (TOS) was made to ensure the proper distribution of the test items. The tool was validated using a 5-point Likert Scale: 5-Excellent, 4- Very Satisfactory, 3-Satisfactory, 2-Fair and 1-Poor.

These tests are particularly useful for evaluating educational programs, instructional strategies, and other interventions. By comparing pretest and post test results, researchers can determine the effectiveness of the intervention (Tiruneh et al., 2014).

Procedure

The rollout of HOTS-PLPs is guided by memoranda such as DM No. 375, s. 2023, which highlights regional training and application of these resources to improve classroom engagement and student outcomes. HOTS-PLP was introduced during the training seminar attended by the researcher and was encouraged to create a learning material that is based on the reference mentioned because of the department lack of references based on PISA and MELCS competencies and utilizing Structure of Observed Learning Outcomes (SOLO) in assessment. After identifying the problem, the researcher developed a Structure of Observed Learning Outcomes Based Metacognitive Approach (SOLO-BAMA) and researcher made test, which was validated by five (5) experts in science. The researcher-made test was tested on some students who had taken and passed the relevant lectures but were not part of the study sample for pilot tests to assess its reliability. The pilot test helped the researchers ensure that the exam was clear, reliable, and consequently a valid assessment of constructs intended to be measured.

Following this, the researcher conducted a validity and reliability test for the research instruments. Upon validating and proving instruments after, the researcher sought the formal approval of the conduct of the study by submitting form of application to the Dean of the Graduate Studies. After approval, the next task was to administer the validated researcher-made test to Grade 8 students of Mamali National High School. The two groups involved in this study were the experimental group, who was taught using Structure of Observed Learning Outcomes-Based Metacognitive Approach (SOLO-BAMA) learning material, and the control group, who followed the Science 8 Learning Module from the Department of Education. This is to make sure that a comparison is only on the same subject content, differing only in instructional approach.

This study was conducted over an eleven-week period, during which the researcher adhered to a week-by-week planned activity noted by the School Academic Coordinator and School Principal. Then, after both groups of students completed the lessons and products, the post-test was administered to assess the effectiveness of the SOLO-BAMA instructional approach in improving the learning outcomes of the students.

In the end, the analysis of the quantitative data from pretests and post-tests would find out if the SOLO-BAMA approach significantly contributed to the improvement of the students' science literacy and creative thinking. This documentation was made to collect data and retrieve processes to allow accurate and reliable meaning for the subsequent organization of analyses and lay down the conclusions of the study.

Data Analysis

To determine the level of the student's performance between controlled group and experimental group in the pre-test and post-test, the mean and standard deviation was used Aloraini (2012). Whereas mean describe the central tendency of a distribution of a particular variable, usually reflecting the most typical case in a data set and when comparing the variability of several data sets is made possible by the standard deviation Mandel (2012).

The Mann-Whitney U test was applied to compare the pretest and post test results of the experimental and control groups (SOLO-BAMA and traditional method). The Mann-Whitney U test is a non-parametric statistical test for examining two independent groups to see whether there is a difference between the scores (Orcan, 2020). The authors justify the use of this test by stating that it is perfect for comparing two groups when dealing with data that may not have a normal distribution (Dytham, 2011).

Results and Discussion

The presentation, analysis and interpretation of the data collected during the study are encompassed in this section. The data were organized into tables to answer the research inquiries outlined in the statement of the problem.

Table 2 shows the comparative results of the students with respect to the pretest and post-test assessments using the SOLO-Based Metacognitive Approach (SOLO-BAMA) and the Conventional Approach. The results from the pretest indicate that both groups began with relatively the same baseline levels of performance. In Science Literacy, the conventional group scored a mean of 66.79 while the SOLO BAMA group scored 68.52. In Creative Thinking, the conventional group's mean was 60.00 while that of the SOLO BAMA Group was 60.28. All these results can be interpreted as "did not meet expectation" which means that students from both groups started with a low to moderate level of proficiency on the measured skills. This equivalence in pretest performance can indicate that the two groups were indeed similar at baseline and this enhances the significance of the post-test results in relation to the assessment of the impact of the teaching

approaches used.

Table 2. *Students' Performance in the Pretest and Post test using SOLO Based Metacognitive Approach and Conventional Approach*

`	*Group*	*Mean*	*SD*	*Verbal Description*
Science Literacy Pretest	Conventional	66.79	1.79	Did not met Expectation
	SOLO-BAMA	68.52	6.29	Did not met Expectation
Creative Thinking Pretest	Conventional	60.00	0.00	Did not meet Expectation
	SOLO-BAMA	60.28	1.02	Did not meet Expectation
	Conventional	81.29	5.38	Satisfactory
Science Literacy Post test	SOLO-BAMA	87.28	4.36	Very Satisfactory
	Conventional	80.00	5.40	Satisfactory
Creative Thinking Post test	SOLO-BAMA	85.20	6.19	Very Satisfactory
Total Pretest	Conventional	63.40	0.90	Did not meet Expectation
	SOLO-BAMA	64.40	3.31	Did not meet Expectation
Total Post test	Conventional	80.65	4.94	Satisfactory
	SOLO-BAMA	86.28	4.96	Very Satisfactory

After the intervention, both groups showed marked improvement; however, those under the SOLO-Based Metacognitive Approach performed the best. The post-test scores for Science Literacy showed the conventional group improving to a mean of 81.29, which is regarded as "Satisfactory". The SOLO-BAMA group improved to a mean of 87.28, which is "Very Satisfactory". Similarly, in Creative Thinking, the conventional group scored 80.00, "Satisfactory", and the SOLO-BAMA group scored 85.20, "Very Satisfactory". In total, the conventional group had a pretest mean of 63.40 and the SOLO-BAMA group 64.40. These marks, although considered "did not meet expectations," indicate that both groups were below the benchmark. Conversely, after the post-tests, the conventional group's average score improved to 80.65, which is classified as "Satisfactory". The SOLO-BAMA group was significantly higher than the conventional group at 86.28, categorizing them as "Very Satisfactory."

The results suggest that although both methods assisted learners, the SOLO-based Metacognitive Approach was substantially more effective. As indicated by Biggs and Collis (1982), SOLO Taxonomy inspires this approach which focuses on the development of higher-order thinking through the completion of structured self-reflective learning tasks. Students in the SOLO-BAMA group showed remarkable improvement which indicates that metacognitive strategies enhance students' deep understanding of concepts and their ability to apply them in original, critical manners. In summary, the study substantiates that the SOLO-Based Metacognitive Approach improves performance relative to other instructional methods, especially in cultivating science literacy and creative thinking.

Table 3. *Difference in the Student's Pre-Test Scores between SOLO Based Metacognitive Approach and Conventional Approach*

	Test	*Mann-Whitney u*	*p*	*Interpretation*
Science Literacy	Pretest	254	0.3604	Not Significant
Creative Thinking	Pretest	264	0.477	Not Significant
Total	Pretest	251	0.3295	Not Significant

The findings in Table 3 present differences in the pretest scores of students taught using the SOLO-based metacognitive approach with those using a conventional approach. For Science Literacy, the Mann-Whitney U value was 254, with a p-value of 0.3604, suggesting no significant difference between the two approaches ($p > 0.05$). For Creative Thinking, the Mann- Whitney U value was 264, and the p-value was 0.477, also providing evidence that the group difference in scores was not statistically significant ($p > 0.05$).

Finally, in the case of the overall pre-test scores, the Mann-Whitney U value was 251, with a p-value of 0.3295, thereby substantiating the conclusion that no significant difference existed between the SOLO-based metacognitive approach and the conventional approach ($p > 0.05$). Thus, these findings indicate that there was no significant difference between the two instructional approaches in the effects on students' performance, at least for the pre-test scores.The null hypothesis states that there is no difference between the distributions in the scores obtained by the two approaches. Since the p-values did not fall below this level, there is no statistically significant evidence supporting one approach over the other concerning the pre-tests.

Absence of a significant difference implies that, the SOLO-based metacognitive approach and conventional approaches may have had similar influences on the pre-test performance of the students in these disciplines. It is possible that other factors, such as prior knowledge, the practice of taking tests, or idiosyncratic qualities of the student, had greater contributions to the pre-test scores than the approach itself. So, it could be that the SOLO-based approach requires more time or practice to allow its greater impact to manifest, as the test may not be sufficient in capturing its full effect.

The results shown in Table 4 indicate a considerable difference in post-test scores of students taught through the SOLO-Based Metacognitive Approach, when compared to conventional approach students. For Science Literacy, a Mann-Whitney U value of 139, with a p-value of 0.001, indicated a significant difference that favored the improvement of post-test scores of students taught using the SOLO-Based Metacognitive Approach as compared to the Conventional Approach. Along similar lines, Creative Thinking also professed a significant difference with a Mann-Whitney U value of 92 and a p-value of less than 0.001, indicating the efficacy of the SOLO-Based Metacognitive

Approach towards improving creative thinking.

Table 4. *Difference in the Students' Post test Scores between SOLO Based Metacognitive Approach and Conventional Approach*

	Test	*Mann-Whitney u*	*p*	*Interpretation*
Science Literacy	Post test	139	0.001	Significant
Creative Thinking	Post test	92	<0.001	Significant
Total	Post test	91	<0.001	Significant

Finally, the aggregate scores on the final tests revealed a significant difference, with a Mann-Whitney U value of 91 with a p-value of 0.001. This further confirms the superior impact of the SOLO-Based Metacognitive Approach in affecting student performance across the board in a more favorable manner than the Conventional Approach. All these findings indicate that it is the SOLO-Based Metacognitive Approach which acts as the important independent variable capable of driving student performance forward in the modules of science literacy and creative thinking.

Table 5. *Learning Gains between Students' using SOLO Based Metacognitive Approach and Conventional Approach*

	Mann-Whitney u	*p*	*Interpretation*
Gain in Science Literacy	175	0.012	Significant
Gain in Creative Thinking	140	0.001	Significant
Total Gain	111	<0.001	Significant

Table 5 shows that the SOLO-Based Metacognitive Approach improved the students' learning gains significantly in science literacy, creative thinking, and overall academic performance. That means that the gain in Science Literacy is highly significant in favor of those students taught using the SOLO-Based Metacognitive Approach (Mann-Whitney $U = 175$, $p = 0.012$); this means that this approach is more effective than the Conventional Approach to improve students' understanding of scientific concepts. Likewise, the gain in Creative Thinking again substantially favors the SOLO-Based Metacognitive Approach (Mann-Whitney $U = 140$, $p = 0.001$), demonstrating that the approach develops creativity. The overall learning gain (Mann-Whitney $U = 111$, $p < 0.001$) further signifies that the SOLO-Based Metacognitive Approach embraces outstanding advances towards increased student learning outcomes. Many previous studies have indicated metacognitive strategies as a means for deeper learning and cognitive development (Rivas et al., 2022).

Conclusions

The conclusion of this study summarizes the key findings regarding the effectiveness of the SOLO-based metacognitive approach in enhancing students' science literacy and creative thinking.

SOLO-based metacognitive approach as significantly improving both students' science literacy and creative thinking. The scores of students in the pretest for science literacy were 68.52 and for creative thinking 60.28, which were in the category of not meeting expectations; meanwhile in the posttest there was an increase to 87.28 and 85.20, respectively, which fell within the very satisfactory grade level. With an overall mean score that improved from 64.40 on the pretest to 86.28 on the post test, improvements can therefore be generalized across all domains as highly significant. The results further provides meaning to the metacognitive SOLO-based method on students' understanding and cognitive ability, especially when compared to conventional research promoting metacognitive strategies in their works by supporting their claims that conventional methods do help the students somewhat, but the improvement is less than that of the SOLO-based methods, thus confirming that rote learning that is teacher-centered will never be able to constructively contribute to the growth of higher-order thinking skills. The findings thus justify introducing metacognitive strategies into education, since that will cultivate deep learning, self-regulation, and cognitive development.

The study produced no significant difference in pretest scores in science literacy, creative thinking, and overall performance between the SOLO-based metacognitive approach and conventional methods. For Science Literacy ($U = 254$, $p = 0.3604$), Creative Thinking ($U = 264$, $p = 0.477$), and the overall score ($U = 251$, $p = 0.3295$), the Mann-Whitney U values all indicated no statistical significance in difference between the two approaches since the p-values were higher than the alpha level at 0.05. This interpretation means that, in general, both instructional methodologies had comparable outcomes where the students were concerned in their respective pretest performances. However, because there was no significant difference, the following factors may play a part: pre-existing knowledge, familiarity with the test-taking process, or characteristics of the students influencing the pretest score. The other reason may include extra time and practice in the application of the SOLO-based approach.

The study shows that SOLO-Based-Metacognitive Approach favored the student performance over the one by traditional. The test for science literacy produced a value of Mann-Whitney $U = 139$ that suggested the significant benefit for the SOLO-based approach ($p = 0.001$). Creative thinking made great gain, too, showing the significant difference with $U = 92$ ($p < 0.001$). In overall scores on the final tests, the difference reached statistical significance as well: Mann-Whitney $U = 91$, $p = 0.001$, thus confirming the predominance of the SOLO-Based Metacognitive Approach when compared to the conventional approach in enhancing students' performance. Such results lay the SOLO-based approach as a key driver for improving science literacy and creative thinking.

The application of the SOLO-Based Metacognitive Approach resulted in remarkable improvements in students' science literacy, creative

thinking, and general academic performance. From the evaluation conducted in science literacy, it was noted that the between-group difference with respect to the gain in scores was quite significant in favour of students taught with the SOLO-BAMA (Mann-Whitney $U = 175$, $p = 0.012$). This clearly points to the understanding of the scientific concepts in teaching methodologies used. With regard to creative thinking improvement, we may conclude that this approach fostered creative thinking in students (Mann-Whitney $U = 140$, $p = 0.001$). The overall learning gain was also found to be significantly better in the group with the SOLO-Based Metacognitive Approach (Mann-Whitney $U = 111$, $p < 0.001$) which supports the notion that the method significantly improved the outcomes of the students.

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