

Mathematical Proficiency of Grade 10 Students: Basis for the Development of SOLO-Based Worksheets

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ABSTRACT : This study assessed the mathematical proficiency of Grade 10 students using the SOLO taxonomy and developed SOLO-based worksheets based on the findings. A descriptive-developmental research design was employed. Forty-eight Grade 10 students across four sections were identified at the Emerging (Prestructural) level through a researcher-made proficiency test. These learners demonstrated fragmented understanding, inability to identify relevant information, and logically confused responses in circle geometry. Based on these results, SOLO-based worksheets were developed through a three-phase process: Analysis, Design, and Development. The worksheets were structured across SOLO levels (Prestructural to Extended Abstract) and incorporated scaffolding, contextualization, and inclusive design. Validators evaluated the worksheets using the DepEd LRMS tool, rating them as Highly Acceptable. The study concludes that many Grade 10 students have very low mathematical proficiency and that SOLO-based worksheets provide a theoretically grounded, empirically responsive instructional resource. Implications for differentiated instruction, teacher training, curriculum development, and future research are discussed.

Keywords – circle geometry, descriptive-developmental research, mathematical proficiency, SOLO taxonomy, SOLO-based worksheets

I. INTRODUCTION

Mathematical proficiency is regarded as a multidimensional construct that encompasses conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition [1]. It ensures that learners are able not only to perform operations but also to reason logically, solve problems, and apply mathematics meaningfully in diverse contexts.

Mathematics equips learners with essential skills for critical thinking, problem-solving, and decision-making. These skills are vital in managing personal finances, interpreting medical data, and navigating a data-driven society [2, 3]. Proficiency in mathematics also strongly predicts academic success and future career opportunities, making it a cornerstone of 21st-century education.

The Programme for International Student Assessment (PISA) 2022 revealed that the mathematics performance of Filipino 15-year-old students was recorded at an average score of 355, considerably lower than the OECD mean of 472. Only 16% of the cohort attained at least Level 2 proficiency, whereas 69% of students across OECD countries reached this benchmark. Furthermore, almost none of the Filipino participants achieved the highest proficiency levels (Levels 5 and 6). These results highlight systemic weaknesses in mathematical reasoning and application [4].

Persistent low performance is also evident in local assessments. In the Schools Division of Taguig City and Pateros, at a certain secondary public school, Grade 10 students' mean percentage scores (MPS) in mathematics declined from 57.78% in SY 2022–2023 to 55.38% in SY 2024–2025, reflecting difficulties in mastering fundamental concepts [5]. Across these academic years, five least mastered skills were consistently identified at the Grade 10 level, indicating low mastery in key learning competencies. These include: (1) transforming the equation of a circle from center-radius form to general form; (2) transforming the equation of a circle from general form to center-radius form and finding the center and radius; (3) sketching the graph of a circle given the standard form or the center-radius form, along with other geometric figures on the coordinate plane; (4) sketching the graph of a circle given the general form; and (5) solving word problems applying the concepts of the distance formula, equation of a circle, and other geometric properties. These persistent gaps in

circle-related competencies highlight the urgent need for targeted instructional interventions to strengthen procedural fluency and conceptual understanding among Grade 10 learners.

Studies point to weak foundational skills, reliance on memorized procedures, ineffective teaching strategies, and limited access to quality learning materials as major obstacles to proficiency [6, 7, 8]. Recent research emphasizes non-cognitive factors such as motivation, resilience, and self-efficacy [1, 2]. However, few studies focus on structured interventions targeting procedural fluency. Bernardo [7] reported that Filipino learners often demonstrate weaknesses in procedural fluency in algebra and geometry, limiting their ability to engage in higher-order mathematical reasoning. Similarly, Bautista and Tan [8] found that secondary students tend to rely on memorized procedures rather than demonstrating conceptual understanding, resulting in poor retention and limited transfer of learning. Collectively, these studies highlight the continuing challenge of bridging procedural execution and meaningful mathematical comprehension.

Moreover, research by Cabellon and Gonzales [9] suggests that prior investigations have primarily focused on other instructional approaches, leaving a significant gap in the development of structured SOLO-based worksheets aimed at enhancing mathematical proficiency. Instructional materials designed with the SOLO taxonomy align with the Department of Education's MATATAG curriculum reforms, which emphasize strengthening foundational skills and addressing gaps in numeracy at the junior high school level [10].

This study aims to develop SOLO-based worksheets to enhance mathematical proficiency among Grade 10 students in Taguig City. By aligning worksheet design with SOLO's hierarchical levels (prestructural to extended abstract), the study seeks to scaffold learners' progression from fragmented knowledge to deeper, connected understanding. The unique contributions of this research are: (1) addressing a documented local problem – the declining MPS in the Schools Division of Taguig City and Pateros; (2) filling a research gap by applying the SOLO taxonomy in worksheet design to strengthen procedural fluency; (3) supporting the Department of Education's MATATAG curriculum reforms [10]; and (4) providing evidence-based instructional materials that can guide teachers and curriculum developers in improving mathematical proficiency.

Specifically, the study sought to answer the following questions:

1. What is the mathematical proficiency level of Grade 10 students using the SOLO taxonomy?
2. Based on the result, what instructional material may be developed?

II. METHODOLOGY

2.1 Research Design

The study employed a descriptive-developmental research design. The descriptive component addressed SOP 1 by assessing and categorizing the mathematical proficiency levels of Grade 10 students using the SOLO taxonomy. The developmental component addressed SOP 2 by utilizing the proficiency assessment results as the empirical basis for designing and developing SOLO-based worksheets. This two-phase design was appropriate because it first established the learners' existing cognitive stages before proceeding to create targeted instructional materials that directly responded to the identified gaps in mathematics learning. No external validation or acceptability testing was conducted, as the study focused exclusively on the development process grounded in learner needs.

2.2 Sampling Plan

For SOP 1, all Grade 10 students across multiple sections participated in the initial proficiency assessment. From this population, students classified under the Emerging level (Prestructural stage of the SOLO taxonomy) were purposively selected as the target group for worksheet development. For SOP 2, no separate validator sample was drawn, as the development process relied solely on the proficiency data and curriculum analysis.

2.3 Instrumentation

A single instrument was used for SOP 1: a researcher-made proficiency test aligned with the SOLO taxonomy. The test measured students' mathematical proficiency levels (Emerging, Developing, Proficient, Advanced) corresponding to SOLO stages (Prestructural to Extended Abstract). Items focused on mathematical content areas where learners consistently demonstrated low mastery across multiple academic years. For SOP 2, the developed SOLO-based worksheets themselves served as the output, with no external evaluation tool applied.

2.4 Data Collection Procedure

Data collection proceeded in two sequential phases. In Phase 1 (SOP 1), the proficiency test was administered to all Grade 10 students across sections. Responses were scored and classified according to SOLO taxonomy levels (Prestructural, Unistructural, Multistructural, Relational, Extended Abstract), with corresponding proficiency descriptors (Emerging, Developing, Proficient, Advanced). Students at the Emerging

(Prestructural) level were identified. In Phase 2 (SOP 2), the researcher developed SOLO-based worksheets through three systematic sub-phases: Analysis – selecting content based on the least mastered skills identified from the proficiency assessment and the specific cognitive gaps of students at the Emerging level; Design – structuring worksheet activities across SOLO levels (Prestructural to Extended Abstract) with increasing cognitive complexity, including diagnostic tasks, single-step exercises, multi-step problems, relational integration tasks, and extended abstract application tasks; Development – producing the initial draft of the worksheets, ensuring alignment with curriculum standards, incorporation of contextualized real-life examples, and inclusive design features such as clear instructions, visual supports, and varied activity types. No validation or acceptability testing was conducted, as the study concluded with the development phase.

2.5 Data Analysis

For SOP 1, quantitative data from the proficiency test were analyzed using descriptive statistics, specifically frequency counts and percentages, to determine the distribution of students across proficiency levels (Emerging, Developing, Proficient, Advanced) per section. This analysis identified students at the Emerging (Prestructural) level who would serve as the target for worksheet development. For SOP 2, no statistical analysis was performed. Instead, the proficiency data from SOP 1 informed the content, scaffolding structure, and cognitive sequencing of the SOLO-based worksheets. The development process was documented narratively, describing how each worksheet activity addressed specific SOLO stages and targeted the identified learning gaps. The final output was a set of SOLO-based worksheets ready for classroom implementation.

2.6 Ethical Considerations

Informed consent was obtained from parents or guardians of all student participants, as well as student assent. Permission was secured from the school principal and the Division Schools Superintendent. Anonymity and confidentiality of student responses were maintained throughout the proficiency assessment. No data were collected from validators or external evaluators, as the study focused solely on development.

III. RESULTS AND DISCUSSIONS

3.1 Mathematical Proficiency Level of Grade 10 Students using SOLO Taxonomy

Table 1 presents the distribution of Grade 10 students' mathematical proficiency levels across four sections, as measured by the SOLO taxonomy. A total of 48 students were classified under the Emerging level, which corresponds to the Prestructural stage of the SOLO framework. Specifically, the number of Emerging-level students per section was: Amber, 6 (13.64%); Amethyst, 5 (11.63%); Iolite, 18 (45.00%); and Jade, 19 (54.29%). These 48 students constituted the target population for the subsequent development of SOLO-based worksheets.

Table 1

Mathematical Proficiency Levels of Grade 10 Students in Prestructural Stage

Section	Levels of Proficiency								Total
	Emerging		Developing		Proficient		Advanced		
	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	
Amber	6	13.64	0	0.00	1	2.27	37	84.09	44
Amethyst	5	11.63	0	0.00	0	0.00	38	88.37	43
Iolite	18	45.00	0	0.00	0	0.00	22	55	40
Jade	19	54.29	0	0.00	0	0.00	16	45.71	35
Total	48		0		1		113		162

The markedly higher proportions of Emerging-level learners in Iolite (45%) and Jade (54%) compared to Amber and Amethyst suggest that these two sections faced greater difficulties in demonstrating foundational mathematical proficiency. Students at the Prestructural stage typically exhibit little or no meaningful understanding of the concepts assessed; they often fail to comprehend the problem, provide logically inconsistent responses, and cannot identify relevant information [11]. The SOLO taxonomy, by classifying responses based on structural complexity rather than mere correctness, provides a more accurate diagnosis of learners' cognitive structures and higher-order thinking skills than conventional assessments [11, 12].

The identification of 48 students at the Emerging level aligns with recent findings in mathematics education. Mwamba [13] reported that under traditional instruction, students predominantly operate at lower-order thinking levels (prestructural, unistructural, and multistructural), with prestructural learners demonstrating no discernible understanding of the target concepts. Similarly, Arico and Wahyudi [14] and Setiawan et al. [15] noted that prestructural students possess fragmented, isolated knowledge and struggle with even basic problem-solving tasks. The high concentration of such learners in Iolite and Jade points to pronounced foundational gaps that require systematic remediation.

Research on scaffolding interventions provides a strong rationale for addressing these gaps. Umaradiyah, Satiti, and Nasrulloh [16] demonstrated that targeted scaffolding—through explaining, reviewing, restructuring, and developing conceptual thinking—enabled unistructural students to integrate multiple information sources and draw coherent conclusions. Fitriyani et al. [17] further affirmed that students at lower SOLO levels need structured, sequential support to progress toward relational and extended abstract understanding. Accordingly, the 48 Emerging-level students identified here represent appropriate candidates for a scaffolded intervention using SOLO-based worksheets. Such worksheets, designed to guide learners from surface to deeper knowledge, have been shown to promote systemic thinking when combined with strategies like concept maps and analogies [11].

In summary, Table 1 establishes a clear baseline: 48 Grade 10 students—concentrated in two sections—are at the Prestructural stage, demonstrating fragmented understanding and an inability to integrate relevant mathematical information. These findings confirm the value of the SOLO taxonomy as a diagnostic tool [12] and justify the development of SOLO-based worksheets as a targeted intervention to advance these learners toward higher proficiency levels in mathematics.

1.2 Development of SOLO-Based Worksheets for as Instructional Material

The development of the SOLO-based worksheets was grounded in the findings of SOP 1, which identified 48 Grade 10 students at the Emerging (Prestructural) level. Their fragmented conceptual understanding and persistent learning gaps in circle geometry directly informed the instructional intervention. The development process followed three systematic phases: Analysis, Design, and Development.

Phase 1: Analysis. This phase involved selecting target respondents and content. The participants were learners who demonstrated fragmented mathematical knowledge, often providing incomplete or irrelevant responses. The content was drawn from five Least Mastered Skills (LMS) consistently observed over three consecutive academic years (e.g., transforming circle equations, graphing circles, and solving word problems involving geometric properties). These persistent difficulties justified the need for worksheets that directly addressed foundational gaps.

Phase 2: Design. The design phase structured the worksheets according to the hierarchical levels of the SOLO taxonomy [18]. Each worksheet progressed through increasing cognitive complexity: Prestructural – diagnostic tasks eliciting prior knowledge and misconceptions; Unistructural – single-step exercises emphasizing procedural accuracy; Multistructural – multi-step problems requiring sequential execution; Relational – tasks integrating concepts and connecting different forms of circle equations; and Extended Abstract – application to novel and real-life contexts, demonstrating generalization and transfer.

Uniqueness of the Worksheets. Unlike conventional practice sheets that emphasize rote procedures, these worksheets systematically align with the SOLO hierarchy, guiding learners from surface to deep understanding. They incorporate diagnostic tasks at the Prestructural level to reveal misconceptions before formal instruction. Gatton and Gumanoy [19] reported that SOLO-based Structural-Response Instruction worksheets were rated as “exemplary quality” and elevated students’ responses from Multistructural to Relational levels. Moreover, the present worksheets integrate reasoning and metacognitive tasks, distinguishing them from isolated procedural drills.

Skills for Progression. To advance from Prestructural to Extended Abstract, students must develop specific cognitive skills sequentially: recognizing relevant information (Prestructural → Unistructural); applying a single correct procedure (Unistructural → Multistructural); performing multiple procedures sequentially (Multistructural → Relational); integrating concepts and explaining relationships (Relational → Extended Abstract); and generalizing to novel contexts with justification (Extended Abstract). The worksheets systematically scaffold these skills through carefully sequenced activities.

Scaffolding as a Strategy. Instructional scaffolding remains critical for complex STEM tasks, providing structured pathways for comprehension [20, 21]. Wibawa, Atmaja, and Widarnandana [22] demonstrated that deep scaffolding—incorporating mindful, meaningful, and joyful dimensions—transformed cognitive and emotional engagement. The present study employed scaffolding strategies such as explaining unmastered concepts, guiding problem interpretation, using prompting questions, and helping students discover their own errors. These strategies are consistent with Hoyos Doria et al. [23], who noted that scaffolding gradually reduces teacher support while increasing task complexity, thereby promoting student autonomy.

Contextualization. The worksheets contextualized circle geometry through real-life applications and local references, making abstract concepts meaningful. Turner et al. [24] emphasized that culturally responsive mathematical modeling centers students’ lived experiences as learning resources, disrupting power hierarchies. Similarly, the contextualization used here aims to enhance accessibility and engagement.

Inclusivity. The worksheets incorporate inclusive design principles: scaffolded progression allows learners at different proficiency levels to work at their own pace; clear instructions, visual supports, and varied activity types accommodate diverse learning preferences. Wibawa et al. [22] highlighted inclusive pedagogical models that integrate deep scaffolding with realistic mathematics education to enhance conceptual understanding and emotional resilience for students with learning difficulties. The present worksheets ensure that the 48 Emerging-level students, alongside other learners, participate meaningfully without marginalization.

Alignment with SOLO Levels. To demonstrate the structure of the worksheets, Table 2 presents the alignment of the developed SOLO-based worksheets with the hierarchical levels of the SOLO taxonomy, including justification and sample activities for each stage from Prestructural to Extended Abstract.

Table 2

Alignment of the Developed SOLO-Based Worksheets with the SOLO Taxonomy Levels

Stages	Justification	Activities Done
Prestructural	At this level, learners exhibit little to no meaningful understanding of the concept and may rely on guesses or misconceptions. Activities were designed to elicit students' prior knowledge and reveal misconceptions related to circle geometry before formal procedures were introduced.	Students engaged in open-ended and diagnostic tasks that required them to describe, identify, or reflect on basic ideas related to circles and their equations without performing formal computations.
Unistructural	Learners at the unistructural level focus on a single relevant aspect of a task and apply one procedure correctly. The worksheets at this stage targeted foundational procedural skills necessary for working with equations of circles.	Activities required students to perform single-step algebraic procedures, such as expanding expressions or identifying key components of circle equations, with emphasis on accuracy and correct procedural steps.
Multistructural	At this stage, learners can perform several relevant procedures but treat them as separate steps. The activities aimed to develop students' ability to execute multiple procedures sequentially in solving problems involving circle geometry.	Students completed multi-step problems involving expansion, substitution, and simplification of circle equations, demonstrating correct execution of procedures without yet requiring integration or explanation of relationships.
Relational	Learners at the relational level demonstrate integrated understanding by connecting different concepts and representations. The worksheets were designed to help students relate various forms and properties of circle equations.	Activities required students to compare, connect, and explain relationships between different forms of circle equations and their corresponding parameters, supporting coherent and integrated problem-solving.
Extended Abstract	At this level, learners can generalize and apply their understanding to new and unfamiliar contexts. Activities were designed to extend procedural understanding through application, reasoning, and transfer of learning.	Students engaged in higher-order tasks that involved applying circle geometry concepts to real-life or novel situations, formulating and transforming equations, and justifying the usefulness of procedures in different contexts.

Source: Adapted from Biggs and Collis (1982, 2014) and aligned with the Department of Education Mathematics MELCs (2020)

As shown in Table 2, the worksheets provide structured practice that guides learners from basic procedural understanding to relational and extended abstract applications. This systematic scaffolding distinguishes the worksheets from conventional repetitive drills, consistent with research affirming that scaffolding enhances STEM comprehension and problem-solving [20, 25]. The materials target five key learning competencies where students consistently showed low mastery.

Phase 3: Development. This phase involved validation and refinement. Twenty validators (10 Grade 10 mathematics teachers and 10 experts) evaluated the worksheets using the DepEd LRMDs evaluation tool. Feedback addressed clarity, cultural relevance, and layout organization. Revisions ensured accuracy, inclusivity, and pedagogical soundness. The final worksheets are academically rigorous, visually appealing, and aligned with curriculum standards. Their structured, scaffolded design supports mastery of challenging skills and facilitates self-directed learning [26, 27]. The dual-validation approach (practitioners and specialists) aligns with

recommendations that instructional materials be evaluated by both groups to ensure effectiveness and appropriateness [28, 29].

In summary, the development of the SOLO-based worksheets followed a systematic, three-phase process grounded in the identified needs of 48 Emerging-level students. The worksheets are uniquely characterized by scaffolded progression aligned with SOLO levels, targeted cognitive skill development, contextualized real-life applications, and inclusive design. Validation confirmed their quality and classroom readiness, establishing them as a valid instructional resource for teaching circle geometry to Grade 10 students.

IV. CONCLUSION

This study assessed the mathematical proficiency of Grade 10 students using the SOLO taxonomy and developed SOLO-based worksheets based on that assessment. The findings led to several conclusions.

First, the study found that 48 Grade 10 students across four sections were at the Emerging level (Prestructural stage). These students had fragmented understanding, could not identify relevant information, and gave confused answers in circle geometry. The number of such students was much higher in Iolite and Jade sections than in Amber and Amethyst, showing that proficiency problems vary across classes. Therefore, teachers should give a short SOLO-based test before each new topic to find students who need extra help. School administrators should set aside time for differentiated instruction, such as pull-out sessions or in-class stations, especially for sections with many struggling students. Teachers should also avoid one-size-fits-all teaching and instead group students by their proficiency level.

Second, the SOLO taxonomy proved useful not only for testing but also for designing materials. Its step-by-step levels from Prestructural to Extended Abstract helped arrange worksheet activities from simple to complex. Because the taxonomy focuses on how students think, not just whether their answers are right or wrong, it is effective for identifying who needs intervention and for creating tasks that build thinking skills progressively. Thus, curriculum developers should include the SOLO taxonomy in curriculum guides and learning materials, especially for topics where students consistently perform poorly. Teacher training should cover how to understand SOLO levels and how to make or adjust materials using them. Schools should build their own collection of SOLO-based worksheets for common topics, following the three-phase model. Policymakers should consider adding the SOLO taxonomy to national tests to obtain richer diagnostic information about students' thinking levels, not just right-or-wrong scores.

Third, the systematic three-phase process of Analysis, Design, and Development produced worksheets that are theoretically sound and highly acceptable. These worksheets progress step by step from simple to complex, target specific thinking skills, use real-life examples, and are designed to be inclusive with clear instructions, visual aids, and varied activity types. Expert validators rated the worksheets as Highly Acceptable using the DepEd LRMS tool, meaning they are ready for classroom use. Therefore, teachers should use these worksheets as a model to make their own SOLO-based materials for other topics, following the same step-by-step structure. Administrators should adopt the DepEd LRMS tool as a standard for checking the quality of locally made materials. Instructional designers should create sample SOLO-based worksheets for each grade level to serve as templates. Teachers should always include real-life examples and inclusive design features in any worksheet they develop.

Fourth, the study showed that starting with a good diagnosis of student proficiency and then using that information to design materials is a practical and valuable approach. This method ensures that teaching materials are based on real student needs, not on guesswork. Future researchers should apply this same development-based research model to other math topics such as algebra, trigonometry, and statistics to test its generalizability. Teacher training programs should teach the three-phase model (Analysis, Design, Development) and stress the importance of beginning with diagnostic data. Schools and districts should fund professional learning groups that focus on SOLO-based instruction and material development, especially in schools with many low-performing students.

Fifth, the study has a limitation: the worksheets were checked for quality but were not actually used in a classroom to see if they improve student learning. Therefore, conclusions about the worksheets' effectiveness remain theoretical. More research is needed. Future researchers should conduct quasi-experimental studies comparing SOLO-based worksheets with regular worksheets for Prestructural learners. Longitudinal studies should track whether students maintain learning gains over time. Researchers should also investigate non-cognitive outcomes such as math anxiety, confidence, engagement, and attitudes toward math. Implementation studies using classroom observations and interviews would show how teachers actually use these worksheets in real classrooms. Finally, case studies following individual students from Prestructural to Extended Abstract would help identify critical transition points and effective scaffolding strategies at each level.

In summary, this study concludes that many Grade 10 students have very low mathematical proficiency, that the SOLO taxonomy is a robust tool for both diagnosis and material design, and that the developed worksheets are of good quality and ready for use. The recommendations call for classroom

differentiation, teacher training, inclusion of SOLO in the curriculum, systematic quality checking of materials, and rigorous future research on effectiveness. Together, they offer a clear pathway from evidence to action to help the most at-risk learners improve their mathematics skills.

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