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Metacognition and Higher-Order Thinking Skills (Hots) in Crafting Lesson Menus in Promoting Scientific Literacy

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ABSTRACT

Science curriculum emphasizes scientific literacy and metacognition as essential competencies for the 21st century and positively contributes to Higher-Order Thinking Skills (HOTS). To support, this study aimed to develop lesson menus that promote scientific literacy based on learners' perceived levels of metacognition, as well as their HOTS. Furthermore, the study aimed to assess the designed lesson menus and determine the learners' scientific literacy, while identifying the significant relationships between scientific literacy and metacognition level, and HOTS, as well as the significant difference between the pre- and post-tests of learners in terms of their HOTS. The study employed a descriptive-developmental design, with 55 Grade 7 learners from the pilot section of Talipan National High School serving as respondents. The study's findings revealed that learners have high awareness in terms of declarative knowledge, conditional knowledge, planning, information management strategies, comprehension monitoring, and evaluation, and very high awareness in procedural knowledge and debugging strategies. Findings also revealed that learners' thinking skills improved from an unistructural to a multistructural level (LOTS) while also attaining a relational level (HOTS) based on the pre-test and post-test results. The designed lesson menus, which included metacognitive and HOTS-based activities, were assessed to demonstrate evidence that all aspects of learning outcomes, learning activities, and evaluating learners' performance had been addressed. Learners' scientific literacy was also found to be very high in terms of body of knowledge, way of thinking, and way of investigating, and fair in terms of the integration of technology and society. Results also indicated a significant relationship between the learners' body of knowledge, procedural knowledge, and way of thinking, as well as their approach to investigating, integrating technology and society, and higher-order thinking Skills (HOTS). There is also a significant difference between the pre-test and post-tests of learners in terms of their higher-order thinking Skills (HOTS), which revealed that the developed lesson menus promoted scientific literacy among Grade 7 learners.

Keywords: *metacognition, lower-order thinking skills, higher-order thinking skills, scientific literacy*

1. Introduction

Education in science is crucial for equipping people with the skills necessary to respond, adapt, and function effectively in various contexts and circumstances, enabling them to face challenging times. Globally, the aim of science education is now scientific literacy (Sutrisna, 2021; Wahab, Wasis, & Yuliani, 2023). Scientific literacy is now essential for overcoming the challenges of the Fourth Industrial Revolution. This is particularly true when learning science, which can immediately interact with everyday phenomena (Widowati, 2017; Ahmad, 2018; Wahab, Wasis, & Yuliani, 2023).

Despite the goal of promoting scientific literacy in young learners to streamline teaching and learning, this presents a serious challenge for teachers, who are the primary drivers of the educational system as reflected from the Philippine's poor ranking in the 2018 and 2022 cycles of Programme for International Student Assessment (PISA) in science, where the country's average science literacy scores placed second-worst out of 78 and third-worst out of 81 participating countries, respectively. According to these findings, most Filipino learners are not prepared for after-school life. This entails a significant focus on increasing research to improve Filipino students' scientific literacy and achieve better performance in international evaluations. Additionally, this suggests that learners should be encouraged to develop their ability to apply Higher-Order Thinking Skills (HOTS) in science to address real-life challenges (Palines & Dela Cruz, 2021; Acido & Caballes, 2024).

The metacognition level of learners is one aspect that affects their capacity to solve science literacy problems. This is because metacognition impacts how students learn. "Thinking about thinking" is a sought-after definition of metacognition, which is the capacity to think critically about something. To comprehend and feel more effectively and efficiently, metacognition is essential for managing and controlling one's mental processes (Pamungkas, Aminah, & Nurosyid, 2019).

Supported by the reviews made by Boğar (2018), several studies have found that metacognitive awareness enhances learning. Students are more successful in the learning process and use learning tools more efficiently when their metacognitive awareness increases. According to the empirical data shown in the studies, some discrepancies exist between metacognition and scientific literacy. These findings can also guide upgrading or innovating classroom lessons to develop better competencies (Khafifi, Sitepu, Yulianto, & Masturi, 2020).

Incorporating metacognition into the curriculum is the most effective method to enhance students' Higher-Order Thinking Skills (HOTS). Teachers often underutilize metacognitive skills as a functional approach to teaching Higher-Order Thinking Skills (HOTS), even though acquiring HOTS is intrinsically tied to metacognitive skills. As a result, teachers face difficulties in incorporating Higher-Order Thinking Skills (HOTS) into their lessons (Liline, Tomhisa, Rumahlatu, & Sangur, 2024).

There is substantial proof that metacognition is necessary for successful HOT in science education (Zohar & Barzilai, 2015). Higher-order thinking and metacognitive skills are crucial for producing students who can compete intellectually in the face of future challenges in knowledge acquisition. Every student should be taught these skills to develop the human capital needed to support the nation in the challenging era of globalization (Sulaiman, Subramaniam, & Kamarudin, 2019).

In this study, the metacognitive model proposed by Schraw (1998) is utilized. Schraw breaks down metacognition into two primary categories: the knowledge of cognition and the regulation of cognition. Two significant points regarding the understanding of cognition and its regulation are the relationship between them and the fact that they are both domain-general due to their broad spectra (Boğar, 2018).

According to the studies made by Crispino-Ceballo and Yangco (2015), Sabna and Hameed (2016); Kallio, Virta, Kallio, and Boğar (2018); Erenler and Cetin (2019); and Hassan, Venkateswaran, Agarwal, Sulaiman, and Burud (2022), Schraw describes the first category, the knowledge of cognition as a person’s own cognitive and the general awareness of what they understand regarding their thinking. Declarative knowledge, procedural knowledge, and conditional knowledge are its three subcategories. Declarative knowledge is the understanding of the learning process and circumstances in which individuals are involved, their cognitive framework, what they are aware of and unaware of, and whether or not they carry out their responsibilities. The understanding of how to apply learning procedures effectively and when to utilize one's learning processes and problem-solving techniques is known as procedural knowledge. In comparison, conditional knowledge refers to understanding how something is carried out, whether it is done alone or not, and under what circumstances.

The second category is the regulation of cognition, which involves an act that controls cognitive knowledge and includes five fundamental parts: planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation. Metacognition encompasses a multitude of metacognitive processes and knowledge used to monitor current thought processes, and several studies have proven that it is closely related to cognitive elements, such as higher-order thinking.

Furthermore, according to Syahputra's (2019) research, as presented in the paper of Sholihah, Sumardjoko, Sumardi, Muhibbin, and Haryanto (2023), in the context of science literacy skills, students find it difficult to respond to HOTS questions since they are unable to remember or understand information, grasp ideas, or understand fundamentals. Teachers use the SOLO taxonomy to plan, define, recognize, and assess learning outcomes, experiences, and assessments across various cognitive difficulty levels, thereby meeting the highly anticipated goals of curriculum creation and competency standards. The SOLO taxonomy can effectively assess students' thinking skills and aptitude, determine their learning strengths and weaknesses, and address any weaknesses (Nunaki, Damopolii, Nusantari, & Kandowangko, 2019).

Teachers use questions as a standard tool in the classroom to elicit responses from their students and assess their understanding of the material. A particular strategy they employ is to use questions to help students understand concepts more deeply by having them answer questions structured according to the SOLO levels. The 5 Levels of Understanding of the SOLO Taxonomy, according to Biggs and Collis (1982), are the following: Prestructural, Unistructural, Multistructural, Relational, and Extended Abstract. The teacher encourages relational and abstract thinking by posing higher-level questions. Effective questioning advances concepts from the basic to the sophisticated.

Teachers can evaluate the quality of their students' learning outcomes using SOLO, which was created to categorize learning outcomes according to their complexity. It can also be used as a framework for characterizing the various degrees of complexity in higher-order cognitive abilities. Learners who are capable of higher-order thinking demonstrate no less than the relational level of SOLO complexity (Pegg, 2020; DepEd, NEAP, RCTQ, PNU & SiMERR, 2022).

According to preliminary studies, scientific literacy is influenced by higher-order thinking skills. Various study's findings demonstrated a linear correlation between scientific literacy and higher-order thinking skills. A science curriculum built on scientific literacy must encompass several key categories. More precisely, Chiapetta (1991) and Udeani (2013) divide scientific literacy into four themes or categories: (1) science as a body of knowledge, (2) science as a way of thinking, (3) science as a way of investigating, and (4) science as an interaction of science, technology, and society.

Science, as a body of knowledge, examines ideas, rules, theories, concepts, and facts. Science as a way of thinking offers a comprehensive overview of science and scientists, particularly in the context of research. Science, as a way of investigating, assigns issues to encourage thinking and action. A summary of the effects of science on society can be found in the interactions between science, technology, and society (Rusilawati, Sunyoto, & Sri Mulyani, 2015; Febriana & Purbayanti, 2022; Murniati, Susilo, & Listyorini, 2023).

Alongside scientific literacy, learners must be effective and employ metacognitive techniques every time they study. Suppose one objective of education is to prepare students for a lifetime of learning. In that case, supporting students in recognizing their knowledge and controlling their activities is essential. When students develop their metacognitive skills, they typically exhibit an increase in confidence (Jaleel & Premachandran, 2016).

Science teachers play a crucial role in fostering students' scientific literacy. Thus, planning learning opportunities and activities is crucial to learners with diverse thinking skills and metacognition levels. With proper planning of science lessons and teaching instructions, scientific literacy in Grade 7 learners can be achieved in the long run. Extensive lesson planning is necessary to effectively incorporate metacognition and Higher-Order Thinking Skills (HOTS) in science learning to promote scientific literacy in learners. According to Karimova and Nasimov (2023), a lesson plan is the teacher's blueprint or instructional roadmap regarding what should be taught to students and how it will be done in the classroom. Teachers can then create learning opportunities for their students and devise ways to assess their development through comments on their progress. The three vital aspects addressed and integrated into an effective lesson plan are objectives for student learning, or the intended learning outcomes; teaching and learning activities; and techniques for evaluating learners' performance.

With Filipino learners consistently underperforming in global assessments, particularly in science, the need to enhance scientific literacy remains a significant concern in the Philippine Educational System. Thus, the recalibrated Science Curriculum has been developed in the new DepEd MATATAG Curriculum. Rooted in the Filipino learners' persistent low achievement on global standardized tests, matched with the ongoing phased implementation of the new MATATAG curriculum, this emphasizes the critical need to direct studies toward scientific literacy.

These changes and development to the educational landscape have led the researchers to explore opportunities to augment the scientific literacy of Grade 7 learners during the initial phase of implementation of the MATATAG Curriculum through investigating their metacognitive awareness and analyzing their HOTS using SOLO Taxonomy.

The current shift in the new science curriculum, although intended to enhance the scientific literacy of learners in its first-phased implementation, poses a greater challenge to teachers due to a lack of resource materials and teacher preparedness to cater to the various skills and levels of thinking of Grade 7 learners regarding the new curriculum goals. Furthermore, as Grade 7 students transition from their elementary years, support in understanding the scientific world is crucial during their formative high school years.

As the foundation of junior high school, Grade 7 learners in the pilot section of Talipan National High School, a very large public secondary school in the district of Pagbilao, located in SDO-Quezon Province, should possess enhanced scientific literacy to work with research-based outputs, such as Science Investigatory Projects (SIP), and be prepared to participate in outside-school activities and events related to science and technology. This will enable them to improve their scientific literacy in their younger years as they journey through junior and senior high school. This study aimed to serve as an enrichment program to enhance the academic experience of Grade 7 learners and challenge them academically, specifically those in the homogeneous pilot class.

Driven to explore these areas as a science teacher to enhance the quality of Grade 7 learners' scientific literacy and improve their metacognitive awareness and higher-order thinking Skills (HOTS) using SOLO-based assessments, this will be further beneficial in developing enrichment activities and planning advanced teaching and learning instructions to create avenues for learners to master lower-order thinking skills and attain higher-order thinking skills in preparation for being a scientifically literate, nation-building citizen in the future. Offering insights into the variables that impact scientific literacy and metacognition, especially in the context of Grade 7 science education, can significantly advance our knowledge of education, particularly in the local context. These findings can influence curriculum design, pedagogical methods, and educational policies that advance scientific literacy and metacognitive abilities.

2. Statement of the Problem

This study aimed to develop lesson menus incorporating metacognition and higher-order thinking skills activities to promote scientific literacy among Grade 7 students of Talipan National High School, S.Y. 2024-2025, specifically for the Quarter 3 lesson on Forces. The study analyzed their metacognitive awareness and higher-order thinking skills (HOTS) using the SOLO Taxonomy.

Specifically, it sought answers to the following questions:

1. How do the learners perceive their level of metacognition using the Metacognitive Awareness Inventory as to:

1.1. knowledge of cognition,

1.1.1. declarative knowledge,

1.1.2. procedural knowledge, and

1.1.3. conditional knowledge

1.2. regulation of cognition,

1.2.1. planning,

1.2.2. information management strategies,

1.2.3. comprehension monitoring,

1.2.4. debugging strategies, and

1.2.5. evaluation?

2. How do the learners' responses on LOTS- and HOTS-based assessments are classified into the SOLO Model as to:

2.1. lower order thinking skills (lots), and

2.1.1. prestructural,

2.1.2. unistructural, and

2.1.3. multistructural

2.2. higher order thinking skills (hots).

2.2.1. relational, and

2.2.2. extended abstract?

3. How is the designed lesson menu utilizing metacognition and HOTS-based activities can be assessed as to:

3.1. learning outcomes,

3.2. learning activities, and

3.3. evaluating learners' performance?

4. What is the scientific literacy of students in pre- and post-assessment in terms of:

4.1. body of knowledge,

4.2. way of thinking,

4.3. way of investigating, and

4.4. integration of technology and society?

5. What challenges and learning improvements do learners encounter?

6. Is there a significant relationship between scientific literacy and:

6.1. metacognition level,

6.2. higher-order thinking skills (hots)?

7. Is there a significant difference between the pre-assessment and post-assessment of learners as to their higher-order thinking skills (HOTS)?

3. Methodology

This study employed a quantitative approach, utilizing a descriptive-developmental research design. The results of the survey and the developed HOTS-based assessments served as the basis for developing lesson menus that incorporated metacognition and HOTS-based activities to promote scientific literacy further. This approach aided in enriching and deepening the learners' understanding of their metacognition levels and HOTS levels by classifying and profiling them according to the SOLO Taxonomy, promoting scientific literacy.

A quantitative method was employed for the metacognitive awareness self-assessment inventory and in analyzing and interpreting the scores obtained in the developed HOTS-based assessment. To further explore opportunities, clarify feedback, and address challenges during the pilot implementation phase of the developed material (Lesson Menus), a qualitative research approach was employed, utilizing semi-structured interviews. This was designed to assess the learners' thinking skills (LOT and HOT), the level of their responses in the assessments based on the SOLO taxonomy, and the challenges or learning improvements they encountered while answering the HOTS-based assessment and the metacognitive awareness inventory.

The respondents of the study were the 55 Grade 7 learners from the homogeneous class of the pilot section of Talipan National High School, Pagbilao I District, Pagbilao, Quezon, who were chosen purposively, as the aim of this study was to provide enrichment or avenues for advanced learners. Additionally, these learners are more exposed and on the frontline of various academic and co-curricular activities; thus, support to enhance their metacognition, Higher-Order Thinking Skills (HOTS), and scientific literacy is crucial. These kinds of learners were the beneficiaries of this study, as it utilized baseline data to provide them with extended learning opportunities and challenges, given that they can easily master the basic competencies compared to other sections. To successfully prepare them for the demands of the new curriculum and academic excellence in Science and Technology, enrichment should be provided to give them more time to study concepts with greater depth, breadth, and complexity.

The research instruments that were employed in the entire study include a metacognition self-assessment questionnaire, LOTS- and HOTS-based assessment in promoting scientific literacy, table of specifications (TOS) for the developed assessment, a rubric with indicator of students' responses for classifying learners into the SOLO Model, a checklist for the developed lesson menus with metacognition and HOTS-based activities on Science 7 lesson, and a semi-structured interview questions for gathering feedback and clarifications on the developed assessment and lesson menus.

The self-assessment questionnaire was the adapted Metacognitive Awareness Inventory (MAI) from Schraw and Dennison (1994), employing a dichotomous question with True or False options. The MAI has two major sections, further divided into subcategories: knowledge of cognition (declarative, procedural, and conditional knowledge), and regulation of cognition (planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation), which consists of a total of 52 statements.

Metacognition is crucial in education since successful lifelong learning requires students to self-regulate their learning habits. As a result, metacognitive skills are crucial for both teachers and students. By creating reliable and valid quantitative measures for psychological phenomena such as metacognition, researchers can contribute to this effort. The Metacognitive Awareness Inventory (MAI) is the most often used assessment for this purpose (Gutierrez, Londoño, Jiménez, Morán, Cuadro, Daset, & Arias, 2024).

This MAI was a widely employed, valid, and reliable tool for assessing the metacognitive awareness of students, which will help researchers incorporate appropriate curricular interventions. Thus, it is one of the instruments that will be utilized in this entire study. One of the studies conducted with MAI is the study by Safitri, Suryani, Asrowi, and Sukarmin (2024). After applying MAI as a metacognition evaluation tool to mathematical problem-solving, it was determined that the questionnaire is a viable and reliable way to assess metacognition as an affective domain. Additionally, it was suggested that to improve students' metacognitive awareness, efforts should be made to integrate the notion of metacognition into the classroom process of solving mathematical problems.

A LOTS- and HOTS-based assessment was developed to test the learners’ scientific literacy, comprising 25 questions: 15 multiple-choice questions, 6 short-answer type questions, and 4 labelling/data completion questions. This was supported by the Table of Specifications (TOS), which incorporated several sub-indicators of the four categories of scientific literacy aligned with the corresponding MATATAG Curriculum Science 7 Quarter 3 competencies.

A rubric with an indicator of students’ responses to classify learners’ responses on the short-answer test as to the SOLO Model (Prestructural, Unistructural, Multistructural, Relational, and Extended Abstract) that was supported by semi-structured interview questions. The questions primarily focused on the learners’ reflection on their metacognitive awareness and self-assessment of how they approach questions that promote LOTS and HOTS.

The study was conducted in three phases. In the first phase, a quantitative-descriptive approach was employed, utilizing a self-assessment questionnaire to identify the metacognitive level of 55 Grade 7 learners and obtain scores from the developed HOTS-based pre-assessment, anchored to the MATATAG Curriculum Science 7 Quarter 3 lesson on forces. Their responses to the open-ended and non-multiple-choice test questions enabled them to be classified at different levels of the SOLO Model.

In the second phase, lesson menus incorporating metacognition and Higher-Order Thinking Skills (HOTS) were developed to promote scientific literacy based on the responses collected from the metacognitive awareness survey and pre-assessment. There was a collection of 8 lesson menus crafted on the Quarter 3 lesson about forces (net force, balanced and unbalanced forces, and free-body diagram) subjected to mixing and matching of one aspect of metacognition – knowledge of cognition (declarative, procedural, conditional), and regulation of cognition (planning, information management, comprehension monitoring, debugging, and evaluation) to one of SOLO Model (Prestructural, Unistructural, Multistructural, Relational, and Extended Abstract). These lesson menus were evaluated by Grade 7 science teachers and a master teacher in terms of the menus’ learning outcomes, learning activities, and evaluating learners’ performance. The crafted lesson menus were utilized for two consecutive weeks, composed of 8 one-hour science class sessions.

After the period utilizing the developed lesson menus, a post-assessment was conducted to determine the scientific literacy of learners in terms of science as a body of knowledge, science as a way of thinking, science as a way of investigating, and science as an integration of technology and society. A gathering of feedback was immediately conducted by conducting semi-interviews with learners to gather their experiences based on the challenges and learning improvements they encountered.

In the final phase, following the analysis above, lesson menus incorporating metacognition and HOTS-based activities were designed to promote scientific literacy in the Science 7 Quarter 3 lesson on Forces, structured according to the official DepEd MATATAG Weekly Lesson Log (2024).

The study adhered to acceptable ethical criteria by obtaining a letter of consent and approval from the appropriate authorities. Since Grade 7 learners are involved in the study, parents' consent was obtained to allow their participation. To ensure the confidentiality of all information gathered from them, the researcher ensured that anonymity was maintained during the collection of pertinent data. All involvement was non-compulsory and did not in any way result in harm or present any hazards.

Frequency, percentage, descriptive statistics, including basic statistical techniques such as mean and standard deviation were utilized to assess the gathered data. For the responses from the semi-structured interviews, thematic analysis was employed to identify recurring themes or patterns related to challenges and learning improvements resulting from the utilization of lesson menus crafted with metacognition and Higher-Order Thinking Skills (HOTS).

The chi-square test was used to identify the relationship between scientific literacy and metacognition level, and Pearson's r was used to determine the relationship between scientific literacy and higher-order thinking skills (HOTS). A paired t-test was used to determine the significant difference in the pre-assessment and post-assessment scores of Grade 7 learners in Science lessons about forces in terms of their Learning Outcomes (LOTS) and Higher-Order Thinking Skills (HOTS).

4. Results and Discussion

Table 1 presents the results of metacognitive awareness among 55 grade 7 students in a homogeneous section, specifically in terms of their knowledge of cognition. The data reveal considerable patterns in students' metacognitive awareness of various kinds of knowledge. The majority of students demonstrate high awareness in terms of declarative and conditional knowledge, as well as very high awareness in terms of procedural knowledge.

Table 1.

Learners' perceived level of metacognition using the Metacognitive Awareness Inventory in terms of Knowledge of Cognition

Declarative Knowledge			Procedural Knowledge			Conditional Knowledge			VI
Score	**f**	**%**	**Score**	**f**	**%**	**Score**	**f**	**%**	
8-9	4	7.27	4	25	45.00	5	17	30.91	**VHA**
6-7	27	49.09	3	18	33.00	4	25	45.45	**HA**
4-5	20	36.36	2	9	16.00	3	10	18.18	**AA**
2-3	4	7.27	1	2	4.00	2	3	5.45	**LA**
0-1	0	0.00	0	1	2.00	1	0	0.00	**VLA**
Total	55	100	Total	55	100	Total	55	100	

***Legend**: Verbal Interpretation (VI): Very High Awareness (VHA), High Awareness (HA), Average Awareness (AA), Low Awareness (LA), Very Low Awareness (VLA)*

Most learners demonstrate a very high level of awareness in terms of procedural knowledge, which means they have a good understanding of which approach is most appropriate and how to carry out a specific activity using their learning methodologies. This high procedural knowledge result may derive from the hands-on, inquiry-based design of science lessons. A very high awareness of procedural knowledge can be attained by continuing to expose learners to the implementation of different procedures or strategies through various situations that facilitate discovery, cooperative learning, and problem-solving, specifically in the context of science learning.

The majority of learners perceived their level of conditional knowledge as high, showing that they have a clear understanding of the circumstances in which such strategies will be used in their learning. It means that learners have a high awareness of choosing the best learning techniques based on the demands of a specific condition. As learners in the pilot section, they are perceived to have a determination to develop their processes and skills to achieve better learning outcomes. Thus, they can monitor their own learning progress and make adjustments to their strategies.

For declarative knowledge, nearly half of the learners perceived their level of awareness as high, which means that learners understand their learning processes, factual knowledge, and strategies. They are highly aware of what they know and what they do not know their strengths and weaknesses, and whether they fulfill their tasks and responsibilities.

The results also showed that, despite the majority of learners having high awareness, there were several learners with average and low awareness, which means that many of them were still facing difficulties in understanding their cognitive processes and what information should be employed to strengthen their learning weaknesses. These scores suggest that learners are exposed to activities that may positively influence their understanding of their learning processes.

The quality of the learners' responses on the Metacognitive Awareness Inventory (MAI) depends heavily on the students' characteristics as they belong to the pilot section, which was pre-classified as learners with above average or high-level academic ability, thus, is closely related to their high ability to be metacognitively aware and be more mindful about what they are doing and know why they are doing.

Although all three sub-domains (declarative, procedural, and conditional) under the knowledge of cognition show minimal numbers of learners with low and very low awareness, this indicates a baseline metacognitive competence across their class. Supported by the study of Bakkaloglu (2020), it is evident that to develop conceptual knowledge or content knowledge, all three categories of cognitive knowledge (declarative, procedural, and conditional) are required, as well as present in successful learners, as backed by numerous studies.

Table 2.

Learners' perceived level of metacognition using the Metacognitive Awareness Inventory in terms of Regulation of Cognition

Planning			**Information Management Strategies**			**Comprehension Monitoring**			**Debugging Strategies**			**Evaluation**			**VI**
Score	**f**	**%**	**Score**	**f**	**%**	**Score**	**f**	**%**	**Score**	**f**	**%**	**Score**	**f**	**%**	
7-8	15	27.27	9-10	9	16.36	7-8	11	20.00	5	35	63.64	6-7	5	9.09	**VHA**
5-6	22	40.00	7-8	29	52.73	5-6	27	49.09	4	16	29.09	4-5	33	60.00	**HA**
3-4	16	29.09	5-6	14	25.45	3-4	12	21.82	3	4	7.27	2-3	14	25.45	**AA**
1-2	2	3.64	3-4	3	5.45	1-2	5	9.09	2	0	0.00	1	2	3.64	**LA**
0	0	0.00	0-2	0	0.00	0	0	0.00	1	0	0.00	0	1	1.82	**VLA**
Total	55	100	Total	55	100	Total	55	100	Total	55	100	Total	55	100	

***Legend**: Verbal Interpretation (VI): Very High Awareness (VHA), High Awareness (HA), Average Awareness (AA), Low Awareness (LA), Very Low Awareness (VLA)*

Table 2 reflects the level of metacognition among learners in terms of their regulation of cognition across its five dimensions. Most learners have a very high awareness of debugging strategies, and the majority showed high awareness in planning, information management strategies, comprehension monitoring, and evaluation.

Learners demonstrate a very high awareness of debugging strategies, indicating that they are highly aware of their strategies to improve their performance and address comprehension difficulties. This shows that whenever they do not grasp the ideas or concepts they are studying, they know what they should do and can eventually correct their errors (self-debugging and peer-assisted strategies). This highlights the idea that being part of a high-performing class, correcting, clarifying, and performance evaluation have been a conventional part of their school life to maintain their standards. As supported by the paper of Hindun, Nurwidodo, and Ghofar (2020), they stated that when a student's performance and comprehension improve throughout learning, debugging techniques are used.

Most learners perceived their metacognitive level in planning as high awareness, which shows that they can determine suitable strategies and materials before undertaking specific tasks. These learners are highly aware of selecting appropriate strategies and allocating resources and time that can affect their performance in achieving results by thinking about what they will do to address the problems they are facing; they are also highly aware of the necessary adjustments and goals before performing a task.

However, considerations for learners who have average and low awareness of planning should be given sufficient attention. Erenler and Cetin (2019), as cited in their paper, noted that students who participated in numerous scientific writing activities in their study showed a significant improvement in the planning component. With these, as young as grade 7 learners they should be exposed to simple scientific writings and scientific investigations, as these require strategic planning skills in terms of goal setting and time organization.

Similarly, the data reveal that the learners have a high awareness of information management strategies, comprehension monitoring, and evaluation, which suggests that learners are highly aware of their strategies and approaches to process and understand the information more effectively, ability to assess performance, application, and progress through learning; and capacity to assess the efficacy of their output, performance, and plan strategy once the learning process is over, respectively. These indicate that majority of learners in the grade 7 pilot section are highly aware of employing a variety of techniques and skill sets to assess their own learning objectives and process information effectively (elaborating, organizing, summarizing, and selectively focusing).

Supported by the claim of Hassan, Venkateswaran, Agarwal, Sulaiman and Burud (2022) that metacognition abilities are of vital importance in a student-centered strategy that gives students autonomy over their learning, thus the incorporation of the abovementioned metacognitive activities were substantial for the enrichment of lesson menus matched with HOTS-based activities in promoting scientific literacy to grade 7 learners from the pilot section.

Table 3.

Classification of learners based on their responses on the LOTS- and HOTS-based assessment as to SOLO Taxonomy levels

Points	Pre-Test		Post-Test		SOLO LEVELS
	f	**%**	**f**	**%**	
Higher-Order Thinking Skills (HOTS)					
3.20 - 4.00	0	0.00	1	1.82	**Extended Abstract**
2.40 - 3.19	1	1.82	24	43.64	**Relational**
Lower-Order Thinking Skills (LOTS)					
1.60 - 2.39	10	18.18	26	47.27	**Multistructural**
0.80 - 1.59	35	63.64	4	7.27	**Unistructural**
0.00 - 0.79	9	16.36	0	0.00	**Prestructural**
Total	55	100	55	100	

Table 3 reveals an improvement in learners' thinking skills from lower-order to higher-order thinking following the development and utilization of lesson menus incorporating metacognitive and HOTS-based activities, as evidenced by the progression from the unistructural level in the pre-test to the relational level in the post-test of the SOLO Model. Prestructural responses were eliminated, and extended abstract thinking emerged in the post-test.

Most of the learners' responses were classified as unistructural in the pre-assessment on the science seven lessons about forces, in which learners could only explain one piece of information or idea about forces without any more explanation. The results mean that learners have background knowledge about forces since they already learned this lesson during their elementary years. Likewise, there is a decrease in the number of learners with unistructural responses from pre- to post-assessment, which indicates further learning of the concepts of forces in Grade 7.

The majority of learners' responses on the post-assessment were classified as multistructural, in which learners were able to answer and employ a variety of data related to balanced and unbalanced forces, net force, and free-body diagrams but were unable to identify any connections between them that prevented them from drawing significant conclusions. While some learners can draw connections between the various concepts underlying forces, these links are not appropriate and lack proper data organization.

Although the multistructural level is still considered lower-order thinking, most of the remaining learners have a relational level, as indicated by their responses on the post-test, which is regarded as deep learning and higher-order thinking. Learners who attained the relational level could apply various information about forces to real-world applications and make connections between the information provided to draw relevant conclusions. Their responses were consistent, as their presented ideas were coherently connected to facilitate comprehension and generalization.

The learner who attained the level of an extended abstract in the post-test was able to draw inferences, make generalizations, and utilize the concepts regarding forces while transferring and applying the principles and ideas to other disciplines (science, technology, and society) and real-life experiences, thus, attaining higher-order thinking based on the open-ended test questions in the assessment provided.

The shift from lower-order thinking to higher-order thinking is understandable and expected, as learners do not have a strong understanding of the lessons on forces, net force, and balanced and unbalanced forces when taking their pre-assessment. However, these findings have significant implications for designing lessons in Science, specifically for high-performing learners like them in a homogeneous class. This indicates that junior high school students (especially grade 7 learners) need proper guidance in scaffolding their thinking from simple to complex.

As cited by Kamal and Badr (2020), when applied to literacy instruction, the SOLO taxonomy framework enables deeper learning that can be adapted to various student learning levels, including the development of thinking skills. Students can improve their cognitive thinking skills by using the questioning method. Additionally, in the study by Damopolii, Nunaki, Nusantari, and Kandowangko (2020), it is claimed that one critical ability that must be developed in the twenty-first century is thinking, and the SOLO taxonomy is specifically used to measure thinking ability and evaluate learners. As science teachers, these results imply that tailored instruction can successfully scaffold students from simple to complex knowledge (Zohar & Dori, 2021).

Table 4.

Assessment of the designed lesson menus utilizing metacognition and HOTS-based activities in terms of learning outcomes

LEARNING OUTCOMES	Mean	SD	VI
1. The specific topic of the lesson is clearly specified.	3.00	0.00	EA
2. The learning objectives are concise and uses clearly defined active verbs of knowledge, skills, and attitudes.	3.00	0.00	EA
3. The learning objectives clearly state valid method of assessment which directly measures learning outcomes.	2.88	0.35	EA
4. The learning objectives directly state metacognitive awareness strategies in an improved learning to various parts of the lesson measurable by different activities.	2.88	0.35	EA
5. The learning objectives let the learners know exactly what is expected of them.	3.00	0.00	EA
6. The learning objectives are developmentally appropriate and suitable for the level of learners.	2.75	0.46	EA
7. The content standards, performance standards, and learning competencies are listed correctly based on the Science 7 MATATAG Curriculum.	3.00	0.00	EA
8. The learning objectives are directly aligned with the standards and correctly unpacked from the learning competencies.	3.00	0.00	EA
9. The learning objectives are directly aligned with standard cognitive difficulty and listed from lower- to higher-level cognitive processes attainable throughout the lesson.	2.88	0.35	EA
10. The learning objectives are attainable within the allocated time frame as reflected on the lesson menus.	2.88	0.35	EA
Overall	**2.92**	**0.15**	**EA**

***Legend**: Verbal Interpretation (VI): 2.34 – 3.00 Evident and all aspects are addressed (EA); 1.67 – 2.33 Evident but lacking some aspects (EL); 1.0 – 1.66 Not Evident (NE)*

Table 4 presents the responses of eight experts, comprising Grade 7 teachers and a master teacher, in evaluating the developed lesson menus with metacognitive awareness and higher-order thinking skills. The results display an overall evident trend, with all aspects addressed, yielding a mean of 2.92 in terms of learning outcomes. The results demonstrate that the designed lesson menus on unit lesson about forces, specifically, net force, balanced and unbalanced forces, and free-body diagram show clarity, alignment, and developmental appropriateness, incorporating metacognitive strategies and higher-order thinking skills within the Science 7 MATATAG Curriculum competencies.

The slightly lowest score in developmental appropriateness suggests areas for minor refinement, potentially in differentiating instruction for diverse learners. These findings are particularly relevant given current emphases on standards-based curriculum design and metacognitive integration in science education (OECD, 2023). The results suggest that teachers can create lesson plans that simultaneously address content standards, metacognitive development, and Higher-Order Thinking Skills (HOTS) progression. The results of this study provide a model for integrating cognitive and metacognitive objectives while maintaining strong curriculum alignment—a crucial balance in 21st-century science education.

Table 5.

Assessment of the designed lesson menus utilizing metacognition and HOTS-based activities in terms of learning activities

LEARNING ACTIVITIES	Mean	SD	VI
1. Learning activities have sufficient details to guide instruction with ease; anyone could understand and use it.	2.88	0.35	EA
2. Learning activities have the potential to arouse interest of target students and actively engages students throughout the lesson.	3.00	0.00	EA
3. Learning activities provide various, clear opportunities for learners to analyze their own progress of mastery of the learning objectives.	3.00	0.00	EA
4. All content presented in the lesson is accurate, clearly connected to the lesson objectives, and useful in understanding the big ideas underlying lesson content.	2.88	0.35	EA

5. Instruction follows a logical sequence – the sequence of activities purposefully scaffolds students toward achieving the lesson's objectives.	3.00	0.00	EA
6. Learning activities foster the development of lower order thinking skills (LOTS) to higher order thinking skills (HOTS).	3.00	0.00	EA
7. Learning activities are differentiated to meet a variety of students' understanding and responses through purposeful questioning to help progress from one SOLO level to another (Unistructural -> Multistructural -> Relational -> Extended Abstract).	3.00	0.00	EA
8. Learning activities promote increasing complexity of students' thinking and understanding using the SOLO levels towards relational and extended abstract.	2.88	0.35	EA
9. Learning activities encourage metacognitive awareness through knowledge of cognition or their general knowledge about what they know about their thinking.	3.00	0.00	EA
10. Learning activities promote metacognitive awareness through regulation of cognition strategies like planning, information management, comprehension monitoring, debugging, and evaluating.	2.75	0.46	EA
Overall	**2.94**	**0.11**	**EA**

***Legend**: Verbal Interpretation (VI): 2.34 – 3.00 Evident and all aspects are addressed (EA); 1.67 – 2.33 Evident but lacking some aspects (EL); 1.0 – 1.66 Not Evident (NE)*

Table 5 shows the responses of the science teachers-evaluators in terms of learning activities which demonstrate that the lesson menus integrated with metacognition and HOTS-based activities contain reflect that the necessary indicators were all addressed and evident for varied learning activities, with an overall mean score of 2.94.

Effective teaching requires teacher planning, specifically creating learning opportunities, which calls for a great deal of expertise, making it a challenging and heavily context-dependent task. Thus, extensive planning for learning activities requires time, research, and alignment with learning objectives and the diverse levels, needs, and characteristics of learners.

These results are particularly relevant considering current educational priorities that emphasize deeper learning and self-regulated learning competencies (Pellegrino, 2021). The high ratings across all dimensions confirm that the lesson menus effectively balance content delivery with the development of cognitive and metacognitive skills through differentiated and individualized activities.

Table 6.

Assessment of the designed lesson menus utilizing metacognition and HOTS-based activities in terms of evaluating learners' performance

EVALUATING LEARNERS' PERFORMANCE	Mean	SD	VI
1. States a clear plan for evaluating mastery of learning objectives.	3.00	0.00	EA
2. Assessment is closely aligned with lesson objectives.	3.00	0.00	EA
3. Assessment prompts are clearly explained and are differentiated in reference to SOLO levels to meet the varied needs of students.	2.75	0.46	EA
4. Assessment strategies are described and an assessment tool such as rubric is given.	3.00	0.00	EA
5. Assessment engages students' higher-level thinking. It supports student choice and encourages students to take responsibility for their learning by having open-ended questions.	2.88	0.35	EA
6. Incorporates methods of learners' self-assessment.	2.75	0.46	EA
7. Applies appropriate assessment strategies to measure student knowledge and improvement in performance at the completion of the learning process.	2.88	0.35	EA
8. Includes explanation of how and when students will receive feedback on assessment.	2.88	0.35	EA
9. Includes student reflection on the level of their metacognitive awareness throughout the lesson.	2.88	0.35	EA
10. Foster students' plan for self-improvement in their metacognitive awareness.	3.00	0.00	EA
Overall	**2.90**	**0.16**	**EA**

***Legend**: Verbal Interpretation (VI): 2.34 – 3.00 Evident and all aspects are addressed (EA); 1.67 – 2.33 Evident but lacking some aspects (EL); 1.0 – 1.66 Not Evident (NE)*

Table 6 displays the results for the evaluation of lesson menus in terms of evaluating learners' performance the evaluation components of the lesson menus demonstrate evidence and all aspects are addressed based on the indicators presented, with an overall mean of 2.90, particularly in their clarity, alignment with objectives, and promotion of higher-order thinking.

The scores for assessment planning, objective alignment, and fostering self-improvement plans highlight the menus' evident integration of standards-based assessment principles (McMillan, 2023). Notably, the inclusion of metacognitive reflection and self-assessment supports the development of higher-order thinking learners, which is a critical outcome in science education.

These findings are particularly relevant given current shifts toward competency-based assessment and formative evaluation practices in STEM education (National Research Council, 2022). The feedback mechanisms and focus on metacognitive growth indicate that these menus move beyond traditional testing to support the holistic development of learners, specifically those in advanced classes.

Effective teaching requires teacher planning, which has been studied from a different facet, including goals, procedures, and outcomes (Lilly, Bieda & Youngs, 2022). Thus, to assess and evaluate whether learners have attained the specific goals for context, skills, or abilities, and to check if there is learning development, a well-structured activity for evaluation should be crafted that perfectly aligns with the given learning objectives.

Table 7 below shows the scientific literacy of students in the pre-test and post-test in terms of science as a body of knowledge, revealing an improvement from very low to very high scientific literacy.

Table 7.

Scientific literacy of students in pre- and post-assessment in terms of body of knowledge

Score	Pre-Test		Post-Test		Verbal Interpretation
	f	%	f	%	
80-100	1	1.82	40	72.73	VH
66-79	24	43.64	15	27.27	H
56-65	0	0.00	0	0.00	F
40-55	0	0.00	0	0.00	L
30-39	26	47.27	0	0.00	VL
0-29	4	7.27	0	0.00	EL
Total	55	100	55	100	

***Legend**: 80-100 Very High (VH); 66-79 High (H); 56-65 Fair (F); 40-55 Low (L); 30-39 Very Low (VL); 0-29 Extremely Low (EL) (Sarini, Widodo, Sutoyo, & Suardana, 2024; Arikunto, 2021)*

The majority of the learners obtained a very high scientific literacy as revealed on their answers on the post-assessment questions in terms of science as a body of knowledge which means that learners were able to consistently identify, explain, and apply scientific and scientific-related knowledge in a range of objects and complex life circumstances through presentation of scientific facts and theories. Learners were also able to formulate sound arguments and resolve issues, support their judgments with evidence through the presentation of scientific hypotheses, and clearly exhibiting scientific thinking in evaluating the most effective scientific method for investigating the hypothesis.

The elimination of scores below 66, coupled with the increase in very high and high levels, demonstrates the positive effect of the developed lesson menus enriched with activities built around HOTS and metacognition. These findings align with current research emphasizing the importance of explicit content integration in metacognitive and HOTS-based instruction (National Research Council, 2022). The results suggest that combining conceptual understanding with higher-order thinking strategies creates an important framework for science learning.

These outcomes are especially relevant in STEM education reform efforts that prioritize both content mastery and scientific reasoning (OECD, 2023). Supported by the study of Rusilowati, Kurniawati, Nugroho, and Widiyatmoko (2016), they claim that to attain scientific literacy in terms of body of knowledge, teachers should teach concepts in great detail; students should comprehend the main idea being taught by the teacher; they should have enough knowledge of scientific facts, terminology, and concepts; and be able to express agreement or disagreement with an issue before offering a scientific explanation.

Table 8.

Scientific literacy of students in pre- and post-assessment in terms of way of thinking

Score	Pre-Test		Post-Test		Verbal Interpretation
	f	%	f	%	
80-100	0	0.00	27	49.09	VH
66-79	3	5.45	20	36.36	H
56-65	7	12.73	6	10.91	F
40-55	22	40.00	2	3.64	L
30-39	8	14.55	0	0.00	VL
0-29	15	27.27	0	0.00	EL
Total	55	100	55	100	

***Legend**: 80-100 Very High (VH); 66-79 High (H); 56-65 Fair (F); 40-55 Low (L); 30-39 Very Low (VL); 0-29 Extremely Low (EL) (Sarini, Widodo, Sutoyo, & Suardana, 2024; Arikunto, 2021)*

Table 8 shows the scientific literacy of students in pre-test and post-test in terms of science as a way of thinking. The results demonstrate an improvement in students' scientific way of thinking following the enrichment, with a shift from low-level thinking to a very high-level way of thinking.

The results reveal that learners can identify forces acting on objects, describe everyday situations that demonstrate balanced and unbalanced forces, and draw free-body diagram (FBD) to represent the relative magnitude and direction of the forces involving balanced and unbalanced forces by answering questions through the use of materials, charts, and tables; calculations and explanation of answers; and involving learners in experiments or thinking activities.

Some learners attained a high level of scientific literacy and were able to apply scientific ideas and scientific knowledge to life circumstances; compare and assess relevant scientific data to address real-world issues through inquiry, making connections and critical thinking; and develop arguments and explanations based on the experimental setup and supporting data presented in tables (Organization for Economic Cooperation and Development (OECD) and Program for International Student Assessment (PISA), 2022).

These gains reflect that the enrichment and developed lesson menus, embedded with metacognitive and HOTS-based activities, have successfully developed students' capacity for scientific reasoning, analysis, and evidence-based thinking—core competencies emphasized in current science education reforms (OECD, 2019).

However, the persistence of learners' responses at fair and low levels suggests that some students may require additional scaffolding to fully develop these cognitive skills. Rusilowati, Kurniawati, Nugroho, and Widiyatmoko (2016) suggested that for learners to achieve high scientific literacy in terms of science as a way of thinking, they should get adequate instruction in critical thinking, inductive and deductive reasoning, causality and scientific data analysis. Learning materials should inform learners about the workings of the scientific world, focusing on thinking, reasoning, and reflection.

The results strongly support the continued emphasis on developing scientific ways of thinking in conjunction with content knowledge. With the recent pilot implementation of MATATAG Curriculum in Grade 7, the researcher believes that with an enormous amount of learning competencies to be covered for a specific period in each quarter, inquiry, collaborative, and discovery learning approaches in science are somehow compromised due to a burden of scientific concepts needed to be imparted to learners. Thus, teachers are allotting more time to lecture discussions to cope with the content knowledge required for specific grade levels.

Table 9.

Scientific literacy of students in pre- and post-assessment in terms of way of investigating

Score	Pre-Test		Post-Test		Verbal Interpretation
	f	%	f	%	
80-100	0	0.00	22	40.00	VH
66-79	0	0.00	21	38.18	H
56-65	8	14.55	8	14.55	F
40-55	17	30.91	4	7.27	L
30-39	9	16.36	0	0.00	VL
0-29	21	38.18	0	0.00	EL
Total	55	100	55	100	

***Legend**: 80-100 Very High (VH); 66-79 High (H); 56-65 Fair (F); 40-55 Low (L); 30-39 Very Low (VL); 0-29 Extremely Low (EL) (Sarini, Widodo, Sutoyo, & Suardana, 2024; Arikunto, 2021)*

Table 9 displays the results on the scientific literacy of students in the pre-test and post-test, focusing on science as a means of investigation. The data reveal gains in students' investigative skills, ranging from extremely low to very high levels.

These reflect that learners can effectively respond to the question intent in terms of understanding and discussing how scientists experiment, the historical development of an idea, empirical nature and objectivity of science, deductive and inductive considerations of science, cause-and-effect relationship, facts and evidence, scientific methods and problem-solving through the MATATAG aligned competencies on in Science 7 Quarter 3 lessons about forces acting on objects, balanced and unbalanced forces, and free-body diagram (FBD) to represent the relative magnitude and direction of forces.

Learners who achieved a high level of scientific literacy were also able to apply scientific concepts and knowledge to real-world situations, compare and evaluate pertinent scientific data to address real-world issues through inquiry, critical thinking, and connection-making, and formulate arguments and explanations based on the supporting data.

These findings demonstrate the impact of the metacognitive and HOTS-based approach in cultivating essential scientific inquiry skills, including experimental design, data interpretation, and evidence evaluation—competencies strongly emphasized in contemporary science standards. The remaining fair-to-low levels suggest that some students may require more intensive support in investigative processes, particularly in scientific practice, connecting evidence to claims—a known challenge in science education (Osborne, 2023).

The findings validate the integration of investigation-focused learning instructions with metacognitive strategy instruction in science classrooms that regularly promote laboratory activities or experimentation, exposing learners to scientific investigations (such as determining independent and dependent variables) and refraining from spending time on rote memorization instead of focusing on science process skills. Learners should also be given regular activities that focus on observing, measuring, classifying, inferring, recording data, experimenting, and other scientific methods (Rusilowati, Kurniawati, Nugroho & Widiyatmoko, 2016).

Table 10.

Scientific literacy of students in pre- and post-assessment in terms of integration of technology and society

Score	Pre-Test		Post-Test		Verbal Interpretation
	f	%	f	%	
80-100	2	3.64	9	16.36	VH
66-79	2	3.64	11	20.00	H
56-65	6	10.91	19	34.55	F
40-55	21	38.18	13	23.64	L
30-39	7	12.73	0	0.00	VL
0-29	17	30.91	3	5.45	EL
Total	55	100	55	100	

***Legend**: 80-100 Very High (VH); 66-79 High (H); 56-65 Fair (F); 40-55 Low (L); 30-39 Very Low (VL); 0-29 Extremely Low (EL) (Sarini, Widodo, Sutoyo, & Suardana, 2024; Arikunto, 2021)*

Table 10 presents the results of the scientific literacy of grade 7 learners based on their pre-test and post-test scores in science, specifically in terms of its interaction with technology and society. The findings demonstrate an increase from a low to a fair level in terms of describing the usefulness, negative effects, problems, and careers and jobs in the field of science and technology for society.

This means that learners demonstrate making inferences about the situations and issues of the role of science and technology from explicit phenomena, directly linking explanations to aspects of life situations from different disciplines of science and technology, and reflecting on behaviors and using evidence and scientific understanding to explain decisions as presented by the questions regarding how the development of MAGLEV trains, as a breakthrough and innovation in modern transportation, was interconnected to science, technology, social issues, and affected society and the economy by offering various kinds of jobs and careers; how does friction play a significant role in the operation of transportation modes like bicycles and cars; and how the production and disposal of lotions and lubricants harm the environment, affect communities and public health, while taking the necessary steps to reduce the negative effects of these products while still benefiting from their use.

For teachers to support learners' understanding of how science, environment, technology, and society interact, it must be ensured that students are aware of the issues based on scientific literacy and propose the necessity of creating assessment tools and materials that are based on scientific literacy and that can gauge students' proficiency in this area to utilize the full extent of current technological sophistication from solid understanding of science (Rusilowati, Kurniawati, Nugroho & Widiyatmoko, 2016).

This pattern suggests that while metacognitive and HOTS-based activities can develop a basic awareness of science-technology-society (STS) relationships, many students continue to struggle with analyzing these connections—a finding consistent with research identifying STS integration as particularly challenging for secondary learners (Sadler, 2021). The results highlight both the potential and limitations of the current approach, revealing that while foundational STS understanding can be developed through metacognitive and Higher-Order Thinking Skills (HOTS) strategies, higher-level integration may require more targeted, context-rich learning experiences (Zeidler & Sadler, 2023).

Table 11.

Thematic analysis of the learners' challenges encountered during the implementation of the lesson menus

Themes	**Subthemes**	**Verbatim data extracts**
1. Difficulty in Goal Setting and Self-Reflection	Lack of Clarity and Awareness of Personal Goals	*"In terms of planning, I do not usually put goals and I don't have actual goals and don't set goals in mind. I found difficulty in the task where I need to determine my personal goals." (S13)*
	Confusion in Metacognitive Activities	*"As I answered the metacognitive awareness survey, I was a little confused at first, since I didn't understand some words, but I mostly checked the "false" boxes because I'm not a very intelligent student." (S13)*
	Struggles in Structured Reflection Activities	*"The task that requires us to enumerate our "Personal Goals" since I don't really have any much goals in life and I don't set up goals." (S13)*
2. Conceptual Difficulties in Science	Difficulty in Understanding and Constructing Free-Body Diagrams (FBD)	*"Kung ire-rate ko po siya 1-10, irerate ko po siya as 8 dahil po sa Free-Body Diagram, Ma'am. Nahihirapan po ako doon. Mahirap po siya sa akin – gravitational, air, normal force, iyong mga forces po na ilalagay doon." (S6)*
	Difficulty in Force Analysis and Vector Representation	*"Medyo nalito lang po ako sa pag-analyze po ng Net Force base sa haba ng arrows po. 'Yong sa Free-Body Diagram po medyo nalilito po kasi ako kung gaano po kalaki ang forces na na-aapply sa mga bagay, doon po sa vectors." (S9)*
3. Collaborative and Time-Pressured Learning	Unequal Participation in Pair Work	*"Medyo nahirapan po ako kasi po, ako po 'yong nagsasagot po talaga hindi po 'yong partner ko po, tumutulong naman po ang partner ko po sa ideas, pero mostly po ay ako po talaga ang nagsasagot. Medyo kinabahan po ako kung tama ang mga sagot ko, pero tama naman po pala." (S5)*
	Time Constraints and Distractions During Collaborative Work	*"Minsan din po ay nakakapressure ang timer o oras para lang magawa 'yong mga activities. Medyo nahirapan po ako sa pagsasagot ng ilang activities dahil sa time pressure po at medyo nadi-distract din po ako sa mga katabi ko po na nagdi-discuss din po ng mga activities." (S4)*

4. Confidence and Motivation Issues	Demotivation due to Complex Tasks	*"May part po kaming nahihirapan doon sa ilang metacognitive activities dahil nakakatamad pong magbasa minsan." (S4)* *"Na-demotivate po talaga ako sa FBD. Doon po ako medyo na-demotivate sa pagsusukat po ng mga forces gamit ang arrows." (S6, S15)*
	Self-Doubt and Low Academic Confidence	*"Sa metacognitive activities, medyo ayaw ko po na tinatanong ako kung natutunan ko po talaga ang lesson dahil hindi naman po talaga sa ayaw, medyo natatanggalan lang po ako ng confidence kasi kapag nalalaman ko po na hindi ko po talaga kaya." (S8)*

Table 11 reveals the themes and subthemes of the learners' verbatim feedback regarding their experienced challenges or difficulties, struggles, worries, confusions, and issues met during the pilot implementation phase of the lesson menus with integrated metacognitive and HOTS-based activities about the lessons on net force, force vector, free-body diagram, and balanced and unbalanced forces, which were collected from a semi-interview made after the enrichment activities and assessments.

Upon answering the Metacognitive Awareness Inventory, some learners were a bit confused about what to do and what the inventory was asking them, as it was their first time completing a survey of this kind. While engaging in metacognitive activities between HOTS-based tasks on forces designed to enhance declarative knowledge, information management strategies, comprehension monitoring, and evaluative skills, some students experienced difficulties in answering reflective questions about their personal goals. They had a hard time enumerating their personal goals before the start of the lesson and assessing whether they met their goals at the end of the lesson, as they were uncertain about what to evaluate. This was because they were unsure about their goals and were not accustomed to setting goals. They were aware and focused on the lesson targets or goals for the concepts and skills they needed to learn and attain during a specific class session.

Some were challenged in terms of analyzing the force vectors or the length of the arrows needed to be drawn for a specific type of force involved in drawing the FBD for a certain situation. These difficulties arose due to a lack of focus, as they mentioned, because they were easily distracted by the other groups or pairs discussing their assigned tasks, and some of them had partners who were not equally exerting effort to think and work as they were. They also admitted that they were a bit distracted because they were working under time pressure. After all, there was only a designated time to finish each task, so they had to think and work quickly, which led to issues in efficiently processing the information. Some learners were hesitant to answer the MAI because they thought that lower scores indicated a lower level of intelligence. As a result, they felt nervous upon learning their weaknesses from the survey, as they were also overthinking whether their provided answers to the activities were correct.

Table 12.

Thematic analysis of the learners' learning improvement encountered during the implementation of the lesson menus

Themes	**Subthemes**	**Verbatim data extracts**
1. Enhanced Self-Awareness and Metacognitive Growth	Self-Discovery and Personal Skill Assessment	*"I found a bit of improvement on myself since I'm a bit of a slowpoke and I can't think fast 'coz it will really hurt my head or twist up some words in my head. But then, after going through all of those, I have realized that there is something I need to improve in myself and gave me a clearer view on what things I need to focus on." (S13)*
	Goal Setting and Reflection	*"Na-realize ko po na may mababang points po ako doon po sa mga time management, nalaman ko po na kulang po ako dito at dapat ko pong i-improve ang paghahati-hati ng oras kung ano po ang dapat ko pong i-prioritize." (S10)*
2. Improved Scientific Conceptual Understanding and Application	Mastery of Force-Related Concepts	*"The most interesting part for me was the FBD-related activities because I was able to connect and use my previous knowledge about forces, specifically, the types of forces to understand and do the FBD for a certain object or situation." (S12)*
	Learning Through Active Engagement	*"The activity that interests me the most was the one where we use the real-life game, the "Arm Wrestle", to identify the different types of forces and I have found out that I am physically weak." (S13)*

3. Development of Higher-Order Thinking Skills	Enhanced Analysis, Critical Thinking and Problem-Solving	*"Nakatulong po ang mga activities para mas ma-analyze po ang mga bagay-bagay at ma-improve po ang critical thinking and problem-solving abilities dahil mas lumawak po ang aking kaalaman." (S3)*
		"Nakatulong po ang mga activities dahil mas napapaunlad po nito ang isip po para mas lalong mag-isip, talagang pagaganahin po ang isipan kung ano po ang mga dapat isagot." (S4)
	Real-World Application	*"The activities in our lesson really affect my critical thinking and problem-solving activities because the activities allowed me to explore on my own and think deeply before answering." (S12)*
4. Motivation and Engagement in Learning	Increased Interest in Science	*"Mas nakatulong po 'yong mga activities para maging malinaw po sa amin kung saan po kami nalilito o kung saan po kami nahihirapan, nababawasan po 'yong mga problema po namin sa academics." (S4)*
	Collaborative Learning Benefits	*"Opo, naapektuhan po ako ng mga metacognition activities. Lalo na po kapag mayroon pong pair / group activities, pinagsasama-sama po namin ang ideas / experience po namin habang nag-aanswer po kami kaya mas natutunan ko po 'yong ilang konsepto sa FBD kahit medyo nahihirapan po ako dito." (S6)*

Table 12 presents the themes and subthemes of the learners' shared learning experiences, highlighting opportunities that promote development, growth, and further learning. Interestingly, the core themes that emerged in the challenges also surfaced as the positive counterparts of their learning improvement. The reason for this may be rooted in the idea that learners found themselves improving because they were challenged to go beyond their existing thinking skills and abilities.

Students reported better self-understanding, many realized their learning habits, and some identified their strengths and weaknesses. The personal experiences of learners during the study revealed that the activities were initially challenging, but they ultimately helped clarify their goals and objectives. Additionally, many had cited a better understanding of the types of forces, including balanced and unbalanced forces, as well as net force calculations with their real-world applications. They believed that the hands-on activities reinforced their understanding of the concepts and improved their observation and reasoning skills through shared experiences in pair and group work, which enhanced idea exchange and debates. With the implementation of various metacognitive and HOTS-based activities in the lesson on forces, many learners became more curious due to interactive tasks that increased their participation.

Based on the responses of learners to the challenges and learning improvement they have experienced, it only shows that the metacognitive and HOTS activities improved learners' views in terms of self-regulation like goal setting and reflection (self-assessment), understanding of scientific literacy (topics on types of forces, balanced & unbalanced forces, FBD, and net force), collaborative and critical thinking skills. These findings align with research on metacognition's role in deeper learning (Veenman, 2017) and HOTS development through inquiry (Zohar, 2020).

Thus, with several positive feedbacks from the students, it may be suggested to expand metacognitive exercises across subjects, use more real-world scenarios to reinforce concepts, and provide differentiated support for varying skill levels. Backed by their responses when asked about what to improve in the process, they requested more critical thinking opportunities, metacognitive activities, and hands-on and collaborative tasks and suggested providing more examples for clarity. They also suggested including the metacognitive awareness survey to learn more about the learners. The learners strongly endorsed the continuation and sustained use of the reflective activities because they were challenged by these and had expressed their appreciation for the activities' application to real life and the teacher's facilitation and support for their continued learning.

Table 13.

Test of the relationship between scientific literacy and metacognition level

Scientific Literacy	Knowledge of Cognition			Regulation of Cognition				
	Declarative	Procedural	Conditional	Planning	Information Management Strategies	Comprehension Monitoring	Debugging	Evaluation
Body of Knowledge	-0.033	0.321*	-0.132	0.209	-0.206	-0.063	-0.166	-0.112
Way of Thinking	0.052	-0.154	-0.047	-0.096	-0.178	0.107	0.074	-0.070
Way of Investigating	-0.145	-0.200	-0.042	0.059	-0.249	-0.119	0.004	-0.124
Integration of Technology and Society	-0.110	-0.031	0.022	-0.019	-0.223	-0.050	-0.022	-0.090

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 13 shows that there is no significant relationship between the domains of scientific literacy and metacognition in terms of knowledge and regulation of cognition, except for the body of knowledge and procedural knowledge.

This one statistically significant correlation suggests that students' very high awareness of their understanding of how to apply scientific processes, which approach is most appropriate and how to use their learning strategies to perform a specific task (procedural knowledge) supports their mastery of core scientific content and the collection of theories on the physical and natural world from various scientific disciplines (body of knowledge). As cited in the study by Goren and Kaya (2023), students must be aware of how they think and learn when analyzing and observing scientific theories to understand and comprehend the nature of science.

Similarly, this may also suggest that individuals with a stronger understanding of scientific facts and principles (the body of knowledge) tend to have a better understanding of how to use and regulate the information and can employ various strategic approaches when resolving issues and difficulties (procedural knowledge). The relationship can be attributed to the notion that if learners know how to apply their knowledge and when to apply the process in completing a task or activity, it will be easier for them to obtain scientific knowledge organized by facts, ideas, rules, theories, hypotheses, and models. On the other hand, if learners have a deep understanding of scientific facts, principles, and laws, specifically regarding to types of forces, net force calculation, balanced and unbalanced forces, and free-body diagram (FBD), and can effectively remember knowledge or information about scientific concepts, then, their understanding of their various learning and memory techniques that are most effective will be much easier.

The reasons for this significant relationship, among others, may be due to several factors. One could be due to the learners' developmental stage, as they were just in grade 7, where higher-order metacognitive skills were still developing. Still, they had stronger procedural knowledge due to its concrete and actionable nature. Supported by the idea that these learners in the pilot section were constantly undergoing a student-centered approach through problem-solving, discovery and cooperative learning in science that enable them better to obtain scientific knowledge (body of knowledge) because they learn and remember concepts in science best after doing hands-on, skill-based, and experiential learning (procedural knowledge), specifically, calculating net force, creating FBD, identifying forces involved and effects of forces to the movement of the objects through simulations. Since learning activities in science require students to be fully engaged and actively involved in experiments and activities, heightening their procedural knowledge, they can easily recall and remember the scientific concepts involved in the procedure, aligning with constructivist theories that emphasize procedural learning in science education (Zohar & Barzilai, 2015). This significant correlation is supported by Husamah's (2015) study, which claims that metacognition level is one of the elements that affects students' capacity to solve science literacy problems, as metacognition influences how people learn.

In contrast, the absence of significant correlations for other metacognitive components implies that metacognitive awareness alone may not be directly related to the other themes of scientific literacy (way of thinking, way of investigating, and integration of technology and society). For the lack of significant correlations with metacognitive components, these results suggest that the dimensions of scientific literacy may not depend heavily on metacognitive awareness, as measured in this study. One reason could be the duration of the study, as it was only conducted for two weeks. Abrupt effects on metacognition may not be visible in the long run, as they must be constantly enhanced in learners. Similarly, due to time constraints in the pilot implementation and with several metacognitive-based HOTS activities, the class sessions operated under compressed schedules, leaving little time for reflective pauses, individual planning, evaluation, strategy discussions and modifications to their approaches.

Table 14.

Test of the relationship between scientific literacy and higher-order thinking skills (HOTS)

Scientific Literacy	HOTS
Body of Knowledge	-0.062
Way of Thinking	0.801***
Way of Investigating	0.459***
Integration of Technology and Society	0.786***

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 14 displays that there is a significant relationship between scientific literacy themes and higher-order thinking skills, except the body of knowledge. The themes of scientific literacy, which focus on active learning and inquiry (a way of investigating), the workings of the scientific effort or thought processes (a way of thinking), and the connections between science, technology, and society, are associated with higher-order thinking skills. These suggest that higher-order thinking skills are linked to students' ability to engage in scientific reasoning, inquiry processes, and real-world applications of science.

With the use of the learning menus with metacognitive-based HOTS activities, learners were guided to improve their higher-order thinking skills affecting their capability to attain higher level of scientific literacy in terms of way of thinking that enabled them to explain answers regarding the different types of forces, effects of forces on objects, and balanced and unbalanced forces through simple activities, games, and actual scenarios; explain answer through the use of pictures, diagrams, tables, and charts regarding force vector, net force, and balanced and unbalanced forces; calculate net force and use simulations on forces; and perform experiments or thinking activities in designing a force measurer and creating FBD.

Learners were also facilitated in enhancing their HOTS to attain a higher level of scientific literacy in terms of way of investigating through lesson menus activities which allowed them to discuss facts and evidence regarding the terms associated with types of forces, net force, balanced and unbalanced forces; present scientific methods in solving problems on force vectors and FBD, provide cause-and-effect relationship when various forces vary in magnitude and direction, and emphasize the empirical nature and objectivity of science through observing, scientific investigations, recording, and analyzing data.

Supported by the studies of Seprianto, Hasby, Sholihah, Sumardjoko, Sumardi, Muhibbin, and Haryanto (2023), there is a direct correlation between literacy and HOTS problem-solving abilities. This connection highlights the importance of literacy skills in optimizing HOTS science problem-solving skills. Students can develop their critical thinking skills to assess information, understand natural phenomena, and formulate insightful questions by cultivating scientific literacy.

This holds true for grade 7 learners who can solve complex issues, make informed choices, and discover possible solutions due to higher-order thinking skills. For them, scientific literacy will be much easier to attain compared to those who struggle with higher-order thinking skills (HOTS). Therefore, scientific literacy skills are not only important for academic purposes but also form a foundation for the development of learners' analytical and critical thinking abilities, which are highly relevant to their lives.

For learners to be able to efficiently measure, observe, classify, infer, record data, compute, and do experimentation (way of investigating); foster curiosity, imagination, reasoning, cause-and-effect links, self-assessment, skepticism, objectivity, and open-mindedness (way of thinking); address social and technological issues that are connected to the nature of science (integration of technology and society), higher-order thinking is a pre-requisite skill.

However, the non-significant correlation with body of knowledge implies that factual knowledge acquisition operates somewhat independently from HOTS development because even learners with LOTS can acquire this body of knowledge with constant exposure, supporting the distinction between "knowing what" and "knowing how" in science education (Duschl, 2021). It also implies that rote memorization of knowledge, such as remembering the definitions of types of forces, balanced/unbalanced forces, free-body diagrams, and recalling the formula for net force, does not always enhance Higher-Order Thinking Skills (HOTS) since these are considered factual knowledge and a lower-order cognitive ability. While HOTS calls for beyond-the-text thinking, which memory alone cannot assist.

Table 15.

Test of difference between the pre- and post-assessment of learners as to their higher-order thinking skills (HOTS)

HOTS	Pre-test	Post-test	t-value	df	p-value	VI
Mean	1.25	2.27	13.8	54	< .001	Significant
SD	0.457	0.441				

Table 15 shows the significant difference between pre-test and post-test of Grade 7 learners based on their HOTS as revealed by the paired samples t-test results, which means that there is a significant improvement in students' higher-order thinking skills from the pre-test following the enrichment activities embedded in the lesson menus (metacognitive- and HOTS-based activities) to post-test.

The HOTS-based activities embedded in the lesson menus scaffold learners' thinking skills toward deep learning in applying various information about forces to real-world applications and making connections between the information provided to draw relevant conclusions while transferring and applying the principles and ideas into other disciplines (science, technology, and society) and real-life experiences, the learners have an increased higher-order thinking in terms of the scientific concepts on types of forces, effects of forces on objects, net force, force vector, balanced and unbalanced force, and free-body diagram.

For grade 7 learners, an increase in their higher-order thinking skills would not only benefit the science curriculum but also improve their quality of life in terms of critical thinking and problem-solving, equipping them to be scientifically ready for the future challenges of the technological and societal world. Being part of the pilot section, this could mean that they were now equipped with higher-order thinking skills to perform scientific tasks and investigations, such as Science Investigatory Projects and other science-related activities.

The reduced standard deviation in post-test scores suggests the enrichment activities had a leveling effect, helping lower-performing students catch up to their peers. These findings gain significance when considered alongside the strong correlations between HOTS and scientific literacy dimensions (Table 14), implying that the enrichment activities likely produced cascading benefits across multiple learning outcomes. The highly statistically significant difference results can be attributed to the significant shift in learners' responses from unistructural (pre-test) to multistructural and relational (post-test) levels of thinking, as reflected in the SOLO taxonomy previously presented in this paper.

The results align with contemporary research emphasizing the malleability of HOTS through targeted instruction (Zohar, 2020), while also suggesting the need for sustained practice to help more students reach the extended abstract level. These findings strongly support the integration of metacognitive and HOTS-focused pedagogies in science classrooms.

5. Recommendations

Based on the results, analysis and findings presented, the researcher has arrived at the following recommendations: First, teachers may consider adding the Metacognitive Awareness survey to their instructions to help learners understand and improve their awareness of their level of metacognition. This may also be given to average and low-performing learners to provide teachers with information on how to gauge their learning. For knowledge of cognition, teachers may consider implementing weekly reflective journaling with guided prompts to deepen self-knowledge and strategy awareness. For regulation of cognition, teachers may consider using different debugging strategies and introduce evaluation rubrics with metacognitive criteria to strengthen weaker skills and maintain strong abilities. Second, it is recommended that teachers continue to design learning activities and materials aligned with the SOLO model to further explore the quality of learners' responses in terms of their thinking skills – LOTS or HOTS. This may also be helpful for teachers to effectively profile their learners in terms of the level of their thinking skills based on the five levels of SOLO taxonomy. By identifying the level of the learner, teachers can provide effective support for students as they transition between SOLO levels (from LOTS to HOTS) through differentiated instruction and activities tailored to their developmental needs and cognitive level. Third, it is therefore advised that teachers develop a repository of exemplars with HOTS-based activities that incorporate embedded metacognitive elements to provide enrichment for high-performing learners. Additionally, teachers should conduct research and benchmarking activities through peer collaboration. Learning menus with differentiated activities allow learners to choose activities that interest them without compromising the lesson's objectives. Fourth, science teachers may consider the four themes in developing the scientific literacy of their learners throughout the teaching of various science concepts, and may focus particularly on enhancing literacy in science as an interaction of technology and society through activities that explicitly apply content knowledge to societal applications. Science teachers may also consider developing learning materials centered on the four themes of scientific literacy to assess learners' literacy, even in distant learning modalities. Fifth, it is advised that teachers continue to vary strategies and learning designs, including individual, paired, and group learning, while allowing learners to constantly monitor their learning phase (self-monitoring). It is also recommended that teachers consider adding metacognitive wrappers to all science lessons and activities, allowing students to continuously reflect on their metacognitive level and level of thinking skills. For the future researchers to further probe the learners' challenges and learning improvements in terms of metacognition, HOTS, and scientific literacy, qualitative study or mixed-method approach may be done to intensify the findings or contribute heavily to existing literature. Sixth, teachers may incorporate systematic metacognitive exercises into science classes, such as self-questioning and regular reflection journals to help students improve their procedural knowledge and foster the growth of scientific literacy and higher-order thinking abilities. Finally, science teachers may keep using and improving teaching techniques that support HOTS, such as inquiry-based learning, problem-solving exercises, and real-world applications to maintain and improve the learners' positive gain after the utilization of these activities.

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