

Scientific Literacy Skills and Their Influencing Factors Among Public School Science Teachers

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ABSTRACT

Scientific literacy skills (SLS) are crucial for effective science education, but context-specific evidence on public-school science teachers' SLS and related school factors remains limited. This convergent mixed-methods study examined the SLS of 19 public-school science teachers using the 28-item Test of Scientific Literacy Skills, which measures understanding methods of inquiry and data processing and interpretation. Results showed that 21% of teachers exhibited high SLS, 63% moderate SLS, and 16% low SLS. Teachers performed best in evaluating the use and misuse of scientific information but showed weaker performance in interpreting basic statistics, reading graphs, and justifying conclusions using quantitative data. Findings suggest that even younger teachers pursuing postgraduate education may struggle with practical SLS, indicating possible gaps in pre-service preparation and professional development. Interviews identified workload, limited facilities, training opportunities, teaching-learning modality, and access to science journals as key influences on SLS.

Keywords: Data analysis, professional development, science education, scientific literacy, time management

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Introduction

Science encompasses abstract ideas and complex methodologies that require systematic and logical approaches, making it challenging. In science education, these demands require teachers not only to teach scientific concepts but also to model scientific literacy skills (SLS). SLS refers to the ability to apply scientific knowledge, processes, and evidence to ask questions, evaluate information, interpret data, and draw evidence-based conclusions (Organisation for Economic Co-operation and Development [OECD], 2013). It is a process of knowledge construction beyond understanding concepts (El Islami & Nuangchalem, 2020), including grasping the nature of scientific knowledge, formulating hypotheses, identifying problems, using reliable methods, and drawing conclusions. Science teachers need these skills to facilitate learning science effectively (Funa et al., 2022; Rubini et al., 2016). Thus, examining teachers' SLS is important because their ability to interpret evidence, evaluate scientific claims, and process data may influence how they guide students in developing similar competencies.

However, their acquisition and implementation are difficult tasks for most teachers because of inadequate training, minimal resources, and ever-changing concepts (Rubini et al., 2017). Additionally, the Philippine public school science teachers also face challenges wherein they experience heavy workloads, and limited laboratory facilities and professional development opportunities (Ulla, 2018). Furthermore, the low performance of the country during the international assessments like Programme for International Student Assessment (DepEd, 2019a; OECD, 2023) emphasizes various gaps in students' scientific literacy, wherein it somehow reflects teachers' own SLS.

Despite these concerns, there is still limited context-specific evidence that explains the level of SLS among Filipino public-school science teachers and the factors relevant to profession and institution that may influence their development.

Therefore, there is a need to conduct this research study to provide evidence on the measured teachers' SLS and the conditions that may support or hinder the enhancement of these skills. Evidence from this study is important to be used in designing more targeted professional development programs, improving systems to support schools, and strengthening practices in public schools' science teaching. The study also responds to the teacher education's current needs, more especially in the preparation of science teachers who have the ability to develop learners' inquiry skills, data literacy, critical thinking, and evidence-based decision-making. Hence, convergent mixed methods, as a research design, was used to investigate the public-school science teachers' SLS, at the same time identifying factors that could influence these various skills. Through the combination of test results with teachers' personal insights, the study is offering recommendations that are practical for improving professional development, support systems, and teaching practices.

Literature Review

Raising SLS is more important especially in the digital age. It encompasses variables as follows: *effective communication, collaboration, quantitative competency, and skills in data interpretation* (Ledbetter, 2012). There is a need for science educators to master SLS, for them to prepare and motivate students for tasks and careers relevant to science (Funa et al., 2023; Pahrudin, 2019). They have a crucial role in

developing citizens and society that could be classified as scientifically literate (Altun-Yalçın et al., 2011; Dani, 2009).

SLS interpretations could range from the application of science in data analysis to a more understanding of it critically (Mohapatra, 2013; Shaffer et al., 2019). To consider oneself as a scientifically literate person, they should be able to evaluate scientific arguments and conduct investigations that advances scientific knowledge (Kilag et al., 2024). These are essential competencies for scientific knowledge and skills to be taught and transferred to students.

There are several studies that have already investigated the SLS of science teachers. In the study of Rubini et al. (2016), they found out that 20% had low SLS, 65% moderate, and 15% high among 25 teachers, wherein these results note challenges like in subject delivery and motivation. According to El Islami and Nuangchalerm (2020), there is a slightly higher SLS for Thai novice teachers than Indonesians, but not significant. Budiman et al. (2021) observed different views on SLS among teachers in the junior high. Dragos and Mih (2015) also stressed in their study that there is a need to understanding educational realities to improve SLS. Bacanak and Gökdere (2009) explored differences in gender that is relevant to preservice teachers' SLS, while Shaffer et al. (2019) linked SLS to various demographic profiles like ethnicity and academic major. Lastly, Aina et al. (2020) also discussed postgraduation SLS and gender gaps.

These abovementioned studies show that the SLS of teachers is influenced by research exposure, disciplinary preparation, professional development, instructional context, and

learning resources access. However, the studies that mostly existed have focused on preservice teachers, general science teachers, or non-Philippine contexts. Taken together, these studies leave limited evidence on how Filipino public-school science teachers might demonstrate SLS and how their own school-based conditions shape their SLS' development.

Hence, there is really a need to study the specific contextual factors that could affect the SLS among Philippine public school science teachers, to develop targeted interventions and to improve education quality in science. The spiraling technique is being used in the Philippine K-12 curriculum that gradually introduces interdisciplinary concepts from simple to complex (DepEd Order No. 21, s. 2019), strengthening the need for teachers to be proficient in all science fields, including SLS (DepEd, 2019b; Walag et al., 2020).

The need to improve SLS is being acknowledged by the Philippine DepEd, particularly after the poor performance of the country in the PISA 2018 and 2022. In here, Filipino students ranked significantly lower compared with their Asian counterparts, like those in Singapore, which highlights a significant gap in education. EDCOM 2 and OECD confirmed such findings. They identified several contributing factors which includes the following: quality of teachers, teaching-learning process, school curriculum, instructional materials, and support by the administrative (EDCOM 2, 2024; OECD, 2018; OECD, 2023).

Framework of the Study

This study is anchored on the SLS framework reflected in the Test of Scientific Literacy Skills (TOSLS) developed by Gormally et al. (2012). The framework views scientific literacy as a set of measurable competencies that enable individuals to evaluate scientific information, understand inquiry processes, interpret data, apply quantitative reasoning, and justify conclusions using evidence. In this study, these competencies are organized into two major domains: understanding the methods of inquiry and data processing and interpretation.

The framework also assumes that teachers' SLS are shaped by the professional and institutional conditions in which they teach and learn. Workload, adequacy of science facilities, access to training, teaching-learning modality, and access to science journals may either support or limit teachers' opportunities to practice inquiry, engage in research, interpret data, and update scientific knowledge. Thus, the study connects teachers' measured SLS performance with the school-based and professional factors that influence their development.

In this framework, the TOSLS results provide the quantitative profile of teachers' SLS, while the qualitative interview findings explain the contextual conditions behind these results. The framework therefore guided the collection, analysis, and integration of the quantitative and qualitative data by linking what teachers demonstrated in the TOSLS with the factors that may support or hinder their scientific literacy development.

Research Questions

This study examined the SLS of public-school science teachers and the factors influencing their development. Specifically, it sought to: (a) determine the overall performance level of public-school science teachers on the TOSLS; (b) describe teachers' specific SLS in terms of understanding the methods of inquiry and data processing and interpretation; and (c) identify the professional and institutional factors that influence the development and enhancement of teachers' SLS.

Participants

This study involved 19 public-school science teachers holding Teacher I-III positions in Philippine Department of Education (DepEd) public high schools. The participants were selected through availability sampling from Master of Arts in Education major in Science Education (MAED-SciEd) students enrolled during the second semester of school year 2021-2022. The sample represented 58% of the eligible MAED-SciEd teacher cohort at the time of data collection. The remaining 42% were not included because of safety and access restrictions during the COVID-19 pandemic, when Sorsogon City was under Alert Level 2 based on the Inter-Agency Task Force guidelines.

With the sample size of the study, the researchers treated the quantitative component as descriptive and exploratory. Hence, the results are not intended to be generalized to all public-school science teachers. Instead, the researchers aimed to providing evidence of the participating teachers' SLS that are context-specific and the professional and institutional factors that may influence their own development. Table 1 presents the participating science teachers' profile.

Table 1*Participant Science Teachers' Profile (n = 19)*

Categories		f	%
Age (years)	23-28	11	58
	29-34	6	32
	35-40	2	11
Sex	Male	3	16
	Female	16	84
Earned units in	0-9	13	68
MAED-SciEd	10-18	6	32
Field of Specialization	Biological Science	10	53
	Physical Sciences	9	47
Length of Service (in years)	5 and below	17	89
	6 and above	2	11

As shown in Table 1, there is a predominantly young cohort with 58% aged 23-28 years and 84% being female. There are 68% teachers who have completed between 0-9 units in their MAED-SciEd program, Biological Science (53%) and Physical Sciences (47%). Also, 89% had teaching experience that is five years or less.

Methodology

Research Design

Convergent mixed-methods design (Creswell & Creswell, 2023) was used in this study. In this design, the researchers collected quantitative and qualitative data at the same time, separately analyzed them, and then integrated them during interpretation. In the quantitative strand, the researchers described teachers' performance using TOSLS, while in the qualitative strand, they explored the perceptions of the teachers

on the professional and institutional factors that might be influencing their own SLS development and enhancement.

The design was deemed appropriate. The study did not only rely to test scores in explaining teachers' SLS. The descriptive profile of teachers' measured skills was provided by the TOSLS, while the interview data helped explain the conditions that may have supported or hindered these skills. The researchers were able to connect teachers performance levels with their lived professional realities, including workload, facilities, training, teaching-learning modality, and access to science journals, through the integration of both the quantitative and the qualitative strands.

Research Instruments and Data Collection Procedures

For the quantitative instrument, the researchers used the TOSLS which was developed by Gormally et al. (2012). This instrument was originally designed for undergraduate students; therefore, its use in this study was limited to descriptively profiling teachers' SLS rather than making broad diagnostic conclusions or generalizations. Also, this instrument was used because its measured skills were aligned with the study's focus, particularly the evaluation ability for scientific information, understanding inquiry processes, interpreting data, applying quantitative reasoning, and justifying conclusions using evidence.

There are 28 multiple-choice items in this instrument. Each targeting one of nine SLS.

In this instrument, there are 2 skill groups as follows: (a) macro-skills: understanding the methods of inquiry (15 items), and (b) data

Table 2*Distribution of test items per skill*

Skills	Items	Total
Understanding the methods of inquiry		(15)
Identifying a valid scientific argument	1, 8, 11	3
Conducting an effective literature search	10, 12, 17, 22, 26	5
Evaluating the use and misuse of scientific information	5, 9, 27	3
Understanding the elements of research design	4, 13, 14, 25	4
Data Processing and Interpretation		(13)
Making a graph	15	1
Reading and interpreting graphical representations of data	2, 6, 7, 18	4
Solving problems using quantitative skills	16, 20, 23	3
Understanding and interpreting basic statistics	3, 19, 24	3
Justifying inferences and conclusions based on quantitative data	21, 28	2

processing and interpretation (13 items). Table 2 presents the distribution of the abovementioned items across the nine skills. Since the TOSLS has not been specifically validated for teacher samples in the present context, this limitation was considered in interpreting the findings.

Before data collection, approval was secured from the University's Campus Evaluation and Review Committee. The participants were informed about the purpose of the study, the procedures involved, and their right to decline or withdraw from participation without penalty. Informed consent was obtained before administering the test and conducting the interviews. To protect anonymity and confidentiality, participants were assigned codes instead of names, and identifying information was removed from the reporting of findings. The researchers securely stored the test results, interview records, and transcripts and used them solely for research purposes.

The data collection had three stages: (a) securing the study approval and the informed

consent, (b) administering the TOSLS using paper-and-pencil tests, and (c) conducting open-ended interviews after the test, which is important to gather contextual explanations, supporting quantitative results. In the paper-and-pencil method, the researchers adhere strictly to safety protocols, which includes physical distancing, within the 1.5-hour duration of the test session. The procedure of giving the test involved giving instructions, distributing and collecting test papers, and maintaining an environment that is controlled and conducive.

For qualitative data, the researchers collected them through open-ended interviews, which was conducted after the TOSLS administration. These interviews are focused on the teachers' experiences, challenges, and perceived factors, which are relevant to influencing the development of their SLS. The participants were allowed to explain conditions that could not be captured by test scores alone through open-ended interviews. Sample interview questions are as follows: "How does your educational background influence your

ability to interpret scientific concepts?” “How do your teaching experiences affect your approach to scientific inquiry?” “What challenges do you encounter in interpreting data, graphs, or basic statistics?” and “How do professional development opportunities affect your confidence in analyzing and applying scientific data?”

Provided there is participants’ consent, The researchers recorded, transcribed, and organized the interview responses. There is approximately 2.5 hours of data generated in the interview, with recurring responses observed.

Data Analysis

The researchers analyzed the quantitative data using descriptive statistics. They used this formula $[(\text{score} / \text{number of items}) \times 100]$, which converts the raw scores from the TOSLS into percentages. Frequencies and percentages were used to describe the distribution of teachers across SLS performance categories. Mean and standard deviation were also computed to determine the general level of teachers’ SLS. Drawing on Arikunto’s criteria as referenced in Rubini et al. (2016), percentage scores were categorized as high, moderate, or low, as shown in Table 3. No inferential statistical test was conducted because of the small sample size and the descriptive purpose of the quantitative strand.

Table 3

Teachers’ SLS Category

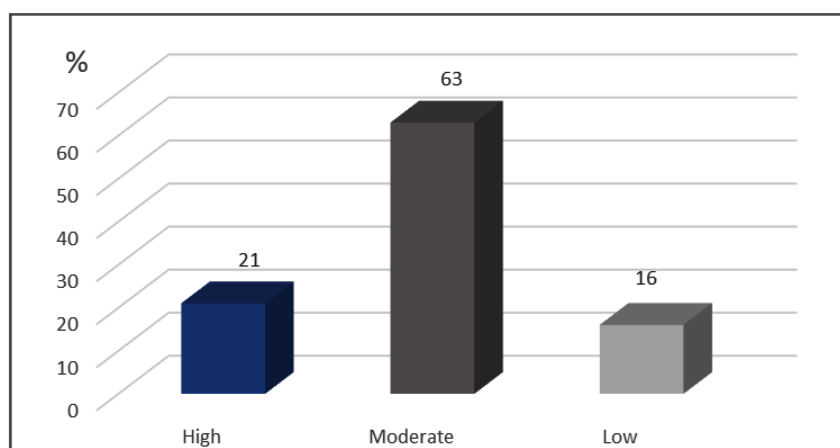
Criteria	Category
Score $> \bar{x} + SD$	High
$\bar{x} - SD \leq \text{Score} \leq \bar{x} + SD$	Moderate
Score $< \bar{x} - SD$	Low

The Arikunto ± 1 SD classification was used only as a descriptive within-sample categorization to group teachers’ TOSLS performance as high, moderate, or low relative to the sample mean. Since there are no established TOSLS cut-off scores for public-school science teachers in the present context, the categories were not treated as standardized proficiency levels. Instead, they were used to support descriptive interpretation and were supplemented by percentage scores per skill area and qualitative interview findings.

For the qualitative data, the researchers used thematic analysis following the general phases of familiarization, coding, theme development, review, and interpretation (Creswell, 2021). Interview transcripts were read repeatedly to identify meaningful statements related to teachers’ experiences in developing and applying SLS. These statements were coded, compared, and grouped into broader categories. The categories were then refined into five themes: workload, adequacy of science facilities, access to science journals, teaching-learning modality, and opportunities for training.

To strengthen trustworthiness, the researchers retained participant excerpts as an audit trail, compared codes across responses, and discussed the emerging themes among the researchers before finalizing the interpretation. The qualitative findings were not used to generalize results but to explain and contextualize the TOSLS findings, particularly why teachers showed moderate overall SLS and lower performance in data processing and interpretation.

After separate analysis, the quantitative and qualitative findings were integrated during interpretation by comparing teachers’ TOSLS

Figure 1*Teachers' Performance on TOSLS*

performance with the themes generated from the interviews. This integration was used to explain how professional and institutional factors may have contributed to the observed SLS performance patterns.

Findings and Discussion

Below are the findings that are presented according to the objectives of the study. First, the overall performance level of teachers on the TOSLS is described. Second, teachers' specific SLS are discussed based on the two TOSLS domains: understanding the methods of inquiry and data processing and interpretation. Third, the qualitative findings are presented to explain how professional and institutional factors may support or hinder teachers' SLS development. In this mixed-methods design, the qualitative data were used to provide context for the quantitative results, particularly the moderate overall SLS and the lower scores in data-related skills.

Performance of the Teachers on the TOSLS

Figure 1 reveals that participants' SLS are distributed as follows: low (16%), moderate (63%), and high (21%). Overall, their SLS fell within the moderate category, suggesting a baseline level with opportunities for enhancement.

These participants were newly enrolled in the MAED-SciEd program. Graduate school affords them opportunities to deepen their scientific knowledge. However, enhancing teachers' SLS cannot be an individual responsibility. Comprehensive supervision plans must be implemented by school administrators in order to provide adequate support and attention to their teachers (Frago & Janer, 2020; Funa et al., 2022).

Teachers' Scientific Literacy Skills

This section presents the details on the teachers' SLS as assessed using the TOSLS. For clarity, the nine specific SLS were consolidated into two categories: understanding methods of inquiry,

and data processing and interpretation (Figures 2 and 3).

Understanding the methods of inquiry

As shown in Figure 2, the participants is capable to assess critically the quality of scientific materials and identify properly the evidence for research claims. With these teachers' skills, students could foster critical and analytical thinking (Adjin-Tettey, 2022; West & Bergstrom, 2021).

Participant 4 noted, "We do not have experience in doing real research studies...our knowledge in the actual execution of research is limited." This sentiment of Participant 4 really reflects that there is a need for graduate education to strengthen the teachers' practical research knowledge and their scholarly confidence (Moriarty, 2018).

Moreover, it was revealed in the results that there is a lack of comprehension regarding research designs. This deficiency may be coming from their roles as Teacher I-III, wherein research is not their primary focus or really part of their work, but rather an optional or personal pursuit. Participant 7 remarked, "We are encouraged

but not mandatory. It is also given low points in promotion." Participant 2 also stated that "There is so much work to do and so many students to attend to." While the teachers are expressing eagerness, in their responses, to engage in research, barriers such as low promotion points, limited funding and time, and heavy workloads impede their participation (Ulla, 2018). Participant 2 contributed, "...if we were to have time and guidance and above all motivation, we could study and conduct proper and meaningful research." From these findings, they underscore the need for enhancing teachers training, resource provision, and support for institutions (Funa et al., 2024).

Data processing and interpretation

Teachers' skills in data processing and interpretation are shown in Figure 3, aligned with moderate category in Figure 1. Some teachers may have exposure to research, but they are lacking hands-on experiences. Participant 12 confirmed this findings stating that "I am familiar with research because I teach research in high school, but I lack confidence because I have not yet published any research articles."

Figure 2

Teachers' SLS on Understanding the Methods of Inquiry

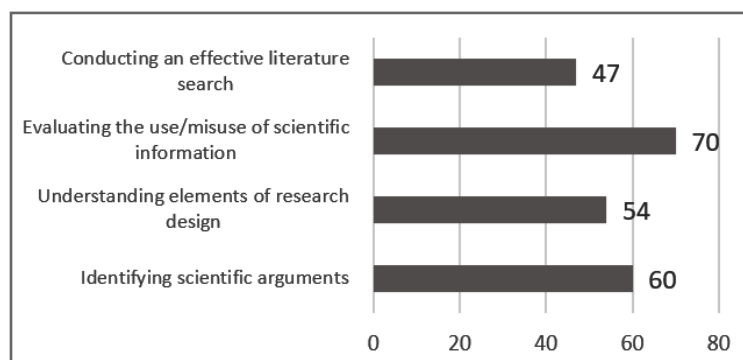
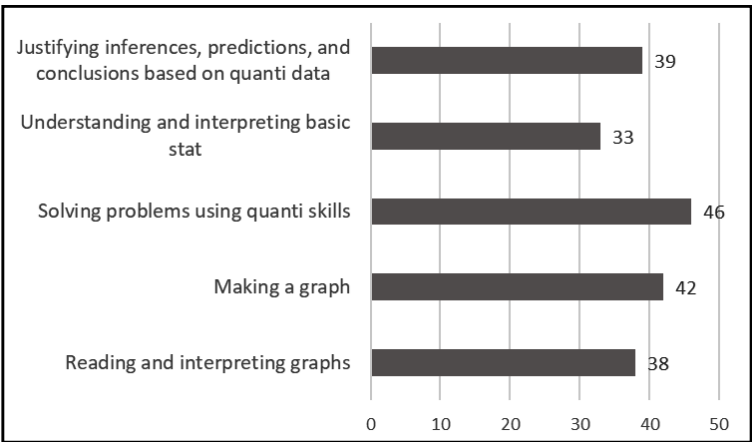


Figure 3

Teachers' SLS on Data Processing and Interpretation



Participant 4 expressed, “I struggle to choose appropriate diagram for presenting data accurately.” However, despite having opportunities for self-learning that are enabled by technologies, it may appear that participants have not fully equipped themselves with skills on constructing graphs. Additionally, Participant 17 remarked, “How can we even study when the internet is so unreliable?” Poor connection to the internet is causing challenges in science education (Funa et al., 2023). Because of this, teachers are restricting self-directed learning, relying primarily on their own personal collections of books and limited library resources that are available and accessible. Participant 17 added, “But there are research books in the library; that’s what we study from.”

Moreover, deficiencies in quantitative and inferential skills are being shown in the responses of participants. Participant 16 articulated, “Analyzing concepts and applying critical skills is challenging without a thorough grasp of fundamental principles.” Furthermore, Participant 9 acknowledged, “I must revisit my mathematics

and reinforce it through tutorials or self-study.” The recognition of foundational knowledge gaps, particularly in mathematics has been emphasized by the abovementioned responses. In addition to these, Participant 1 queried, “...how can I effectively impart these skills to my students without possessing them myself?” This kind of inability to teach someone beyond their own skill is recurring in themes. These findings are consistent with studies (Ledbetter, 2012; Shaffer et al., 2019), emphasizing that literacy in science requires competence in the interpretation of quantitative data, and evidence-based reasoning. They support also the earlier findings that limited engagement in research, insufficient resources, and weak institutional support may affect the ability of the teachers to develop skills that are research-related and data-oriented (Ulla, 2018; Yalçın & Altun-Yalçın, 2017).

Factors that affect the enhancement of the Science Teachers’ SLS

For qualitative findings, they explained the various conditions behind the TOSLS results.

Table 4*Lists of factors that affect the teachers' SLS from the interviews*

Themes	Subthemes
Workload	• Excessive teaching loads • Performs ancillary tasks • Additional reports
Adequacy of Science Facilities	• Inappropriate science laboratory • Inadequate science equipment and materials • Classroom converted to laboratory
Opportunity for Training	• Limited training opportunities • Limited funds for training • Most trainings are localized
Teaching-Learning Modality	• Preference for face-to-face classes • Preference for passive learning • Limited teaching methods
Access to Science Journal	• Limited access to e-science journals • Limited subscription for printed science journals

Comparing with the quantitative data that showed that most teachers had moderate SLS and lower performance in data processing and interpretation, the qualitative data from the interviews revealed why these gaps may persist in practice. There are five themes that emerged from teachers' actual accounts, and these are as follows: workload, adequacy of science facilities, opportunity for training, teaching-learning modality, and access to science journals (Table 4). These themes show that teachers SLS are shaped not only by their own individual abilities, but also by time, resources, institutional support, and research-related learning opportunities.

Workload

One of the critical factors that emerged is the Workload. The multiple ancillary tasks like property custodian, disbursement officer, bookkeeper, and coordinator, among others are affecting the responses of the participants coming from small schools (Into & Gempes, 2018). These additional responsibilities are

consuming the time and energy of the teachers that could have been otherwise dedicated to their own professional growth and research. Participant 14 remarked and supported this finding stating that "With the numerous forms we need to complete, we really can't find time for research." Participant 11 also confirmed, "With the overwhelming tasks, we often use our vacant time for work." This heavy workload limits the teachers' opportunities in engaging works related to research, which is one of the important factors for SLS development. While research requires mental acuity, creativity, and critical thinking, it also demands significant time investment (Banal & Ortega-de la Cruz, 2022). If teachers are overwhelmed with excessive workloads, they may find it challenging to dedicate time to research activities.

The themes were interpreted in relation to the quantitative findings. Workload and ancillary tasks help explain why teachers may have limited time to engage in research, data analysis, and professional reading. Inadequate

science facilities help explain limited exposure to hands-on inquiry and experimentation. Limited training opportunities help explain gaps in research design, statistics, and interpretation of quantitative evidence. Teaching-learning modality reflects how pandemic-related learning arrangements affected teachers' opportunities for direct inquiry-based instruction. Limited access to science journals explains difficulties in conducting literature searches and updating scientific knowledge. Together, these themes provide a contextual explanation for the moderate overall SLS and the weaker performance in data processing and interpretation.

Adequacy of Science Facilities

The inadequacy of science facilities further limits hands-on experimentation, a critical component of developing scientific literacy. Many teachers reported teaching science theoretically due to a lack of functional laboratories and updated equipment (Peniero & Toshihiko, 2020). In smaller schools, classrooms are sometimes repurposed into makeshift laboratories, which restricts the types of scientific investigations. Participant 2 emphasized, "How can we conduct research experiments when we lack the necessary facilities, even for classroom experiments?" Participant 4 added, "...basic supplies...for the classroom are unavailable." Participant 13 further commented, "We teach in theory, but lack hands-on experience."

In big public schools, some classrooms are converted into laboratories. On the contrary, for small schools, the chance is quite nil, unless they are identified as a beneficiary of government projects (Janer & Deri, 2020). In the absence of such facilities, teachers conduct experiments solely in their classrooms and choose experiments based on available resources

or sometimes opt to show videos. Participant 14 remarked, "It's fortunate that we now have the internet; sometimes I just download experiment videos." This resourcefulness allows students to learn basic scientific concepts through simple activities. However, this practice may provide limited opportunities for demonstrating and developing SLS (Al-Kandari et al., 2019).

Opportunity for Training

Training provides SLS enhancement (Svendsen, 2020). With such broadened knowledge, teachers may be able to communicate complex ideas with students and answer typical misconceptions better. Furthermore, training helps teachers design interesting lessons, conduct experiments, and utilize technology-oriented methods. Participant 18 admitted, "We acknowledge the need for training to raise our scientific literacy levels."

In most cases, different teachers are gathered and motivated to share their experiences and discuss their challenges through training. Participant 8 supported this findings stating, "In trainings, we meet educators from different schools and exchange knowledge and experiences." Participant 10 added, "training opens collaboration opportunities." The collaboration, in this sense, fosters continuous professional development and creates a network that is supportive for teachers, where they can grow and refine their practices. Emphasized by Participant 8 is the Reflective Practice during training, encouraging educators to analyze their teaching methods, evaluate student outcomes, and make necessary adjustments.

It is encouraged to recognize the importance of training, wherein schools should participate in offered refresher courses, seminars, and ICT and

curriculum planning workshops (Vibal & Janer, 2023). However, despite its apparent significance, still, many teachers find it hard to attend to these kinds of opportunities due to budget constraints. They usually are compelled to cover expenses out of their own pockets. To ensure attendance to trainings, schools provide support by allowing official travel time. Participant 4 noted, “There are training courses funded by the school, but sometimes we have to spend our own money.”

The mentioned funding challenges are common (Omeodu & Amadi, 2018). Moreover, trainings are becoming optional since it is not mandatory in promotions and competency profiles of Teachers I-III (Llego, 2014). Optional training could create inequity, a double-edged sword that allows flexibility, but do not provide much-needed training for professional development. Those teachers who have resources to spend for their own trainings could gain from increased skills and knowledge, but those who do not could miss significant opportunities that may result in uneven levels of skill.

Teaching-Learning Modality

The teaching-learning modality is one of the identified themes that shaped SLS development. Teachers’ analytical and critical thinking skills were challenged by the shifts to purely modular and online instruction during the COVID-19 pandemic. Participant 19 supported this idea stating, “Asynchronous learning modality is difficult. I prefer in-person learning because concepts can be thoroughly discussed and explained.” This sentiment underscores the difficulty of adapting to alternative learning modalities. Face-to-face classes enable direct communication that allows immediate interaction, feedback, and engagement (Funa et al., 2023; Gherheș et al., 2021).

However, what has always been brought to the fore regarding learning processes by the pandemic is the need to teach SLS through various modalities (Funa & Talaue, 2021; Ramallosa et al., 2022). “I actually learned to use computers during the pandemic, which are useful even when the pandemic is over,” Participant 10 highlighted.

While in-person classes offer huge benefits, remote learning environments can also offer excellent opportunities in honing SLS. The internet with its wealth of materials and engaging tools could supplement the teaching. Alternatively, hybrid models may balance the two modalities (Marchisio et al., 2022).

Access to Printed Science Journals

Journals are important in updating scientific knowledge because they represent peer-reviewed research articles, aimed at communicating recent findings, theories, and developments. However, Participant 5 pointed out, “...need money to access the journals. Our school and library do not subscribe...” Participant 8 echoed, “...to access them is quite rigorous...” Access to some journals is costly and limited. To address this issue, schools may consider open access initiatives and expand educational resources. Participants 14 and 19 similarly noted their inadequate access to reliable sources.

The challenges identified by teachers in developing their SLS appear to be prevalent not only among public school educators (Ulla, 2018) but also among academicians. Yalçın and Altun-Yalçın (2017) found that academicians also faced difficulties in data analysis, time constraints, issues with collaborative work, and challenges accessing international research resources.

Integration of Quantitative and Qualitative Findings

The integration of quantitative and qualitative findings shows that teachers' SLS cannot be understood through test scores alone. The TOSLS results indicated moderate overall SLS, with stronger performance in evaluating the use and misuse of scientific information and weaker performance in data processing and interpretation. The qualitative findings explained these patterns by showing that teachers' opportunities to develop SLS were constrained by heavy workloads, limited research engagement, inadequate facilities, restricted access to journals, and insufficient training. Thus, the qualitative data strengthened the interpretation of the quantitative results by identifying the professional and institutional conditions that may contribute to teachers' measured performance. The findings from this integration supported the need for in-service training with target, improved access to research resources, and institutional support for science teaching that is inquiry-based and data-oriented. Consistent with previous research studies, this interpretation shows that teachers' SLS is shaped by professional development, exposure to research, instructional context, and learning resources access (Rubini et al., 2017; Svendsen, 2020; Ulla, 2018).

Conclusion and Recommendations

This study examined the SLS of the public-school science teachers by determining their overall performance, assessing their scientific inquiry and data interpretation skills, and identifying the professional and institutional factors affecting their development. The findings address the limited evidence on the SLS of practicing Filipino science teachers,

particularly in resource-constrained public-school settings.

For the first objective, most participants have demonstrated moderate SLS. This indicates that the teachers possessed foundational SLS but did not demonstrate advanced competence consistently. The finding supports the view that SLS progressively develops and not automatically ensured by academic qualifications, graduate education, or experience in teaching.

For the second objective, participants better performed in scientific information evaluation and valid scientific arguments identification. However, they showed weaker skills in searching literature, designing research, basic statistics, graph interpretation, and drawing conclusions from quantitative evidence. These results support the multidimensional view of scientific literacy, in which competence in scientific claims evaluation does not necessarily indicate data analysis and evidence-based reasoning proficiency.

For the third objective, the participants have identified major scientific literacy influences such as heavy workloads, inadequate science facilities, limited training opportunities, teaching-learning modality, and restricted access to scientific journals. These conditions limited their opportunities to conduct research, perform scientific investigations, interpret data, and update their knowledge. The findings show that SLS is shaped not only by individual competence but also by institutional resources, professional opportunities, and support from the organizations.

Overall, the study concludes that the SLS of the teachers results from the interaction between individual competencies and professional conditions. For ASEAN teacher education, the findings support approaches

that are contextualized and multidimensional that integrates scientific inquiry, information evaluation, data interpretation, and evidence-based reasoning. Teacher education institutions should provide authentic research experiences, statistical and graphical literacy activities, inquiry-based laboratory work, and training in scientific communication. Schools and education agencies should provide also the sustained professional development, research mentoring, access to laboratories and scholarly resources, protected research time, and manageable workloads. These competencies may be incorporated into ASEAN teacher standards, accreditation requirements, and continuing professional-development policies.

The findings should be carefully interpreted considering the small availability-based sample of 19 MAED-SciEd teachers from a single setting. COVID-19 restrictions also affected participant recruitment and data collection. Moreover, the TOSLS was originally developed for undergraduate students and has not been fully validated for practicing teachers in the local context. The findings are therefore descriptive and generalization to all Filipino or ASEAN science teachers should be careful.

Future research may involve samples that are larger and diverse across school types, regions, science specializations, and ASEAN countries. Studies should validate or adapt the TOSLS for practicing teachers and examine the effects of targeted interventions in research design, statistics, graph interpretation, and evidence-based reasoning. Longitudinal and cross-national studies may also investigate how teacher education, institutional support, workload, and access to resources influence teachers' SLS and classroom practices.

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Statements and Declarations

1. Funding details

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2. Disclosure statement

The authors declare no competing interests.

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4. Ethical Approval

The study was approved by the University's Campus Evaluation and Review Committee and the Research and Extension Council.

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