

Development and Standardization of Pisa–Based Chemistry Questionnaire (PISA-BCQ) For Senior High School Learners

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DOI: <https://doi.org/10.47772/IJRISS.2026.100600105>

Received: 27 May 2026; Accepted: 01 June 2026; Published: 18 June 2026

ABSTRACT

This study aimed to develop, validate, and implement a PISA-Based Chemistry Questionnaire (PISA-BCQ) to assess senior high school learners' performance in General Chemistry and identify the least mastered competencies. Employing a descriptive-survey research design, the study involved learners from a public secondary school in Iligan City, Philippines. The research instrument consisted of a fifty (50)-item multiple-choice questionnaire aligned with the PISA Science Framework and DepEd's Most Essential Learning Competencies (MELCs). The instrument underwent expert validation, pilot testing with 150 learners, and item analysis to establish its reliability, difficulty, and discrimination indices. Descriptive statistical tools such as mean, frequency, and percentage distribution were utilized to analyze learners' performance, while Cronbach's alpha was used to determine internal consistency. Results revealed that the PISA-BCQ exceeded expectations in all validation criteria and demonstrated acceptable reliability ($\alpha = 0.7407$). Implementation findings indicated generally low levels of learner mastery, with 43% of learners failing to meet performance expectations and none achieving outstanding proficiency. Analysis of learners' responses identified that *Chemistry in Everyday Life* is in *Not Mastered Level*, meanwhile *Thermochemistry and Kinetics*, *Organic and Biochemistry*, *Nuclear Chemistry and Solutions*, *Acids*, and *Bases* are the *Least Mastered Level Competencies*. These results highlight significant learning gaps, particularly in applying Chemistry concepts to real-life contexts and understanding abstract processes. The study concludes that the PISA-BCQ is a valid and reliable diagnostic assessment tool and recommends the integration of PISA-aligned, contextualized instructional strategies to improve learners' chemistry performance and science literacy.

Keywords: Educational Assessment, General Chemistry, Least Mastered Competencies, PISA-Based Chemistry Questionnaire, Science Literacy, Senior High School Learners

INTRODUCTION

Science literacy refers to learners' capacity to engage with science-related issues and ideas as reflective and responsible citizens. Scientifically literate individuals can participate in reasoned discourse about science and technology, which requires competencies such as explaining scientific phenomena, evaluating and designing scientific investigations, interpreting data, and using scientific evidence to support conclusions (OECD, 2019).

Despite its importance, international assessments reveal that science literacy among Filipino learners remains a significant concern. Results from the Programme for International Student Assessment (PISA) indicate that the Philippines performed substantially below the Organization for Economic Co-operation and Development (OECD) average in science literacy. Specifically, Filipino learners obtained a mean score of 357 compared to the OECD average of 489 (Leikuma-Rimicane, et al. 2022). This considerable gap highlights the need for a critical review of possible contributing factors, including the implementation of the K–12 curriculum, teacher preparedness, student readiness for international large-scale assessments, and other contextual variables that may influence learning outcomes.

Educational assessment plays a vital role in evaluating the quality of education and informing policy and practice. PISA assesses learners nearing the end of compulsory education and provides insights into how well education systems prepare learners to apply scientific knowledge and skills in real-life contexts. Beyond measuring academic performance, PISA serves as an additional tool for examining curriculum effectiveness, instructional practices, and even teacher performance. Moreover, the assessment allows for the analysis of learners' scientific reasoning processes and the influence of contextual factors—such as learning environments and instructional approaches—on science achievement (Cordon et al. 2020).

Within the broader domain of science education, chemistry presents unique challenges for both teaching and learning at the secondary and tertiary levels. Chemistry concepts often involve abstract, microscopic, and symbolic representations that contradict learners' intuitive and everyday experiences. As a result, learners frequently develop misconceptions when attempting to interpret chemical phenomena through the lens of their pre-instructional conceptions (Zhang and Treagust, 2020). Students' academic performance remains a persistent challenge in education (Tekkumru-Kisa et al., 2021). As the central agents of the learning process, students' performance directly influences the attainment of educational goals and objectives. In science education—particularly in Chemistry—student performance is especially critical, as it reflects learners' ability to understand abstract concepts, apply scientific reasoning, and engage in problem-solving tasks (Ardura & Pérez-Bitrián, 2019; Ramnarain & Ramaila, 2018; Zhang et al., 2021). These misconceptions can hinder meaningful understanding and negatively affect learners' performance in assessments that emphasize scientific reasoning and application, such as PISA.

Addressing these gaps is particularly important in the context of international assessments, where learners are expected to demonstrate not only content knowledge but also higher-order scientific competencies. This study is also aligned with the United Nations Sustainable Development Goals (SDGs), particularly SDG 4: Quality Education and SDG 17: Partnerships for the Goals. SDG 4 emphasizes ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all, which is directly addressed by this study through its focus on improving learners' science literacy and strengthening chemistry education. By examining science competencies and assessment practices informed by international benchmarks such as PISA, the study contributes to efforts aimed at enhancing the quality, relevance, and effectiveness of science instruction. Furthermore, the study supports SDG 17 by drawing upon international assessment frameworks and research collaborations, highlighting the importance of global partnerships, shared standards, and evidence-based practices in advancing educational improvement and policy development.

Objectives

The primary objective of this study is to determine the least mastered competencies in General Chemistry among learners using a PISA-based research questionnaire. Specifically, this study aims to:

- a) Develop and evaluate a fifty (50) item PISA-Based Chemistry Questionnaire (PISA-BCQ) aligned with the PISA Science Framework and the Most Essential Learning Competencies (MELCs) in General Chemistry.
- b) Assess learners' performance in General Chemistry using the developed and validated PISA-aligned Chemistry questionnaire.
- c) Identify the least mastered Chemistry competencies and topics based on learners' performance in the assessment results.

METHODOLOGY

The study utilized a descriptive-survey research design, as it aims to describe learners' performance in General Chemistry and identify the least mastered competencies using PISA-Based Chemistry Questionnaire (PISA-BCQ). Focusing on the collection and analysis of quantitative data without manipulating variables. The research was conducted in a public secondary school in Iligan City, Philippines, involving senior high school learners who had sufficient exposure to the targeted General Chemistry competencies.

The primary research instrument was a fifty (50) item PISA - Based Chemistry Questionnaire (PISA-BCQ) aligned with the PISA Science Framework and the Most Essential Learning Competencies (MELCs). The instrument underwent expert validation, pilot testing with one hundred fifty (150) learners, and item analysis to establish reliability, difficulty, and discrimination indices before being administered to learners during the implementation phase. Data collection followed the ADDIE instructional design model, ensuring a systematic process of analysis, design, development, implementation, and evaluation.

Data analysis employed descriptive statistics, including mean, frequency, and percentage distributions, to determine learners' performance levels and identify least mastered competencies. Instrument reliability was established using Cronbach's alpha. Ethical considerations were strictly observed throughout the study, including informed consent, voluntary participation, confidentiality of data, and compliance with the Data Privacy Act of 2012.

RESULTS AND DISCUSSION

This chapter presents the analysis and interpretation of the data, with findings summarized in tables and discussed to address the study's objectives.

Validator's Ratings on PISA-Based Chemistry Questionnaire (PISA-BCQ)

This section summarizes the ratings and feedback gathered from the instrument validators regarding the PISA - Based Chemistry Questionnaire (PISA-BCQ). Their focus is on enhancing the cognitive levels of the questions, ensuring alignment with key principles, and optimizing the format to ensure a well-structured and meaningful assessment tool.

Table 1. Validator's Rating on the PISA-Based Chemistry Questionnaire (PISA-BCQ)

Parameters	VA	VB	VC	Mean	Interpretation
Content and Validity	4.00	3.92	3.94	3.95	Exceed Expectation
Clarity of Wording	3.94	3.92	3.92	3.92	Exceed Expectation
Appropriateness of Difficulty	4.00	4.00	3.94	3.98	Exceed Expectation
Quality of Distractors	3.98	4.00	3.92	3.96	Exceed Expectation
Format and Consistency	3.98	4.00	3.92	3.96	Exceed Expectation
Alignment with Learning Objectives	4.00	3.92	3.92	3.94	Exceed Expectation
Overall	3.9	3.9	3.0	3.6	Exceed Expectation
Legend: 3.26 - 4.00 (Exceed Expectation), 2.51 - 3.25 (Met Expectations), 1.75 - 2.49 (Below Expectation), 1.00 - 1.74 (Not Applicable): V= Validator					

Table 1 of the expert validation indicates that the developed PISA - Based Chemistry Questionnaire (PISA-BCQ) *exceeded expectations* across all evaluated parameters. In terms of content and validity, the instrument obtained a high overall mean of 3.95, suggesting that the items were appropriate, relevant, and aligned with the intended Chemistry competencies. Similarly, the clarity of wording received an overall mean of 3.92, indicating that the test items were clearly stated and easily understood by the target respondents. The appropriateness of difficulty level yielded the highest overall mean of 3.98, reflecting that the test items were suitably challenging for the learners and consistent with their academic level. The quality of distractors and format and consistency

both obtained an overall mean of 3.96, demonstrating that the multiple-choice options were well-constructed and that the questionnaire followed a consistent and organized format. Furthermore, the alignment with learning objectives garnered an overall mean of 3.94, confirming that the test items were closely aligned with the General Chemistry learning objectives and the Most Essential Learning Competencies (MELCs). The PISA-Based Chemistry Questionnaire (PISA-BCQ) achieved a general mean rating of 3.60, which falls within the descriptive range of “*Exceed Expectation*.”

This finding suggests that the instrument is valid, clear, and appropriate for assessing learners’ performance in General Chemistry and is suitable for use in identifying least mastered competencies. This study is supported by the findings of Manseguiao, et al. (2024), who highlighted that a needs assessment revealed a significant demand for the development of a comprehensive learning packet for the participating school.

The PISA - Based Questionnaire (PISA-BCQ) Reliability, Difficulty and Discrimination Result

This section focuses on the reliability analysis of the research instrument, highlighting the Cronbach’s alpha coefficient used to assess its internal consistency.

Table 2. Reliability Result of the PISA-Based Questionnaire (PISA-BCQ)

Cronbach α	Interpretation	Variance	No. of Items
0.7407	Acceptable	42.05	50

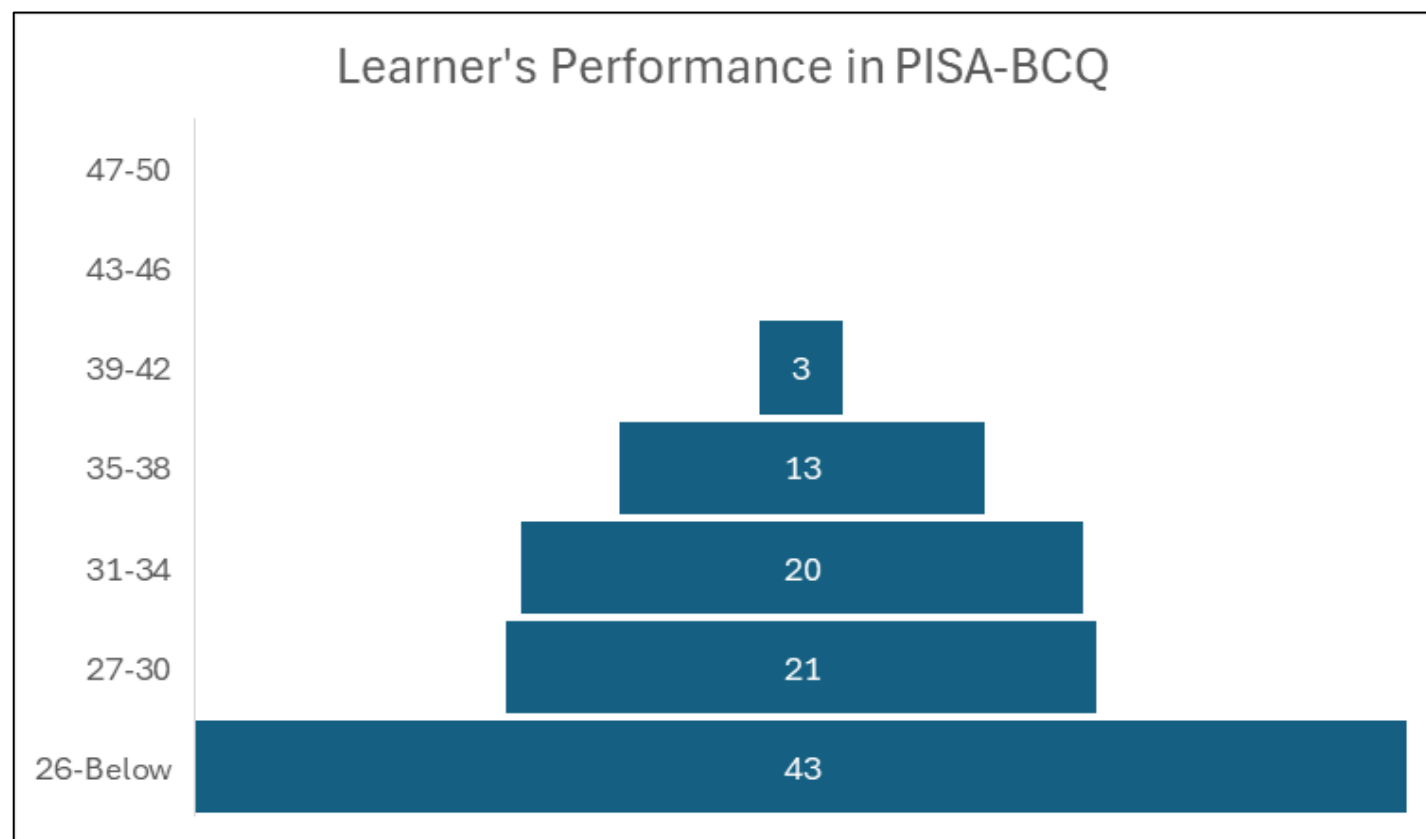
The reliability analysis of the PISA - Based Chemistry Questionnaire (PISA-BCQ) yielded a Cronbach’s alpha coefficient of 0.7407 based on fifty (50) items administered to one hundred-fifty (150) learners. This value indicates an acceptable level of internal consistency, suggesting that the items in the questionnaire are sufficiently related and consistently measure the intended General Chemistry competencies. According to commonly accepted standards in educational research, Cronbach’s alpha value of 0.70 and above reflects satisfactory reliability, confirming that the PISA - Based Chemistry Questionnaire (PISA-BCQ) is a dependable instrument for assessing learners’ performance and identifying least mastered competencies in General Chemistry. This value exceeds the recommended threshold of 0.7, indicating that the scale reliably measures the latent variables (Fornell & Larcker, 1981; Nunnally, 1978; Nunnally & Bernstein, 1994).

Item analysis showed that all fifty (50) items of the PISA-Based Chemistry Questionnaire had *AVERAGE* difficulty levels, indicating that the instrument was appropriately calibrated for the target learners. Most items demonstrated fair to good discrimination indices, effectively distinguishing between high- and low-performing learners. The findings confirm the psychometric soundness of the questionnaire and its suitability for assessing General Chemistry performance and identifying least mastered competencies. The PISA-Based Chemistry Questionnaire (PISA-BCQ) also underwent a readability assessment in which all items were evaluated using the *Simple Measure of Gobbledygook (SMOG)* Index. The results of this assessment informed revisions to item wording, sentence structure, and vocabulary, thereby ensuring clarity and accessibility while maintaining content accuracy.

Implementation Result of the PISA-Based Chemistry Questionnaire (PISA-BCQ)

This section presents the results of the implementation of the PISA-Based Chemistry Questionnaire (PISA-BCQ), which was administered to senior high school learners to assess their performance in General Chemistry. The findings summarize learners’ score distributions, performance levels, and mastery of Chemistry competencies based on the finalized and validated assessment instrument. These results serve as the basis for identifying the least mastered competencies and for drawing conclusions regarding learners’ overall Chemistry performance.

Figure 1. Learner's Performance on the PISA-Based Chemistry Questionnaire (PISA-BCQ)



Legend: Outstanding = 43-50, Very Satisfactory = 35-42, Satisfactory = 31-34, Fairly Satisfactory = 27-30, Did Not Meet Expectations = 26 - below. Reference: DepEd Order No.8 s. 2015

Figure 1 presents the final scores of the PISA-Based Chemistry Questionnaire (PISA-BCQ) for a sample of one hundred (100) learners, along with their corresponding percentage ranges and performance interpretations. The distribution of learners' scores reveals that none of the respondents achieved Outstanding performance, as no learners obtained scores within the ranges of 47–50 and 43–46. Only three learners (3%) attained scores ranging from 39–42, while thirteen learners (13%) scored between 35–38, both of which fall under the *Very Satisfactory* level of performance. These results indicate that a limited number of learners demonstrated high proficiency in the assessed General Chemistry competencies.

A greater proportion of the respondents achieved *Satisfactory to Fairly Satisfactory* performance. Specifically, twenty learners (20%) scored within the 31–34 range, interpreted as Satisfactory, while twenty-one learners (21%) obtained scores between 27–30, corresponding to a Fairly Satisfactory level. These findings suggest that a substantial number of learners possess basic understanding of the Chemistry concepts assessed, though further reinforcement may be needed.

Notably, the largest group of respondents, comprising forty-three learners (43%), scored 26 and below, which is interpreted as *Did Not Meet the Expectations*. This result indicates that nearly half of the learners exhibited low mastery of the General Chemistry competencies measured by the PISA-Based Chemistry Questionnaire (PISA-BCQ). Overall, the score distribution highlights the need for targeted instructional interventions and curriculum support to address learning gaps and improve learners' performance in General Chemistry.

These findings are consistent with previous research by Kunting, Nabua, and Salazar (2022), who emphasized that student performance is influenced not only by the inherent complexity of the subject matter but also by their depth of mastery over the content. Furthermore, Orongan et al. (2019) underscored the persistent challenges learners face in understanding science disciplines, particularly chemistry, due to their abstract and conceptual nature. This highlights an urgent need for innovative and effective instructional strategies that simplify complex

concepts, making them more accessible and relatable to learners, thereby improving comprehension and academic achievement in chemistry.

The Least Mastered Competency Result

In this section is the result of the Least Mastered Competency Result in General Chemistry ranking the Mastered, Nearly Mastered, Least Mastered and Not Mastered Competencies.

Figure 2. The Mastery Level of the Learners in General Chemistry

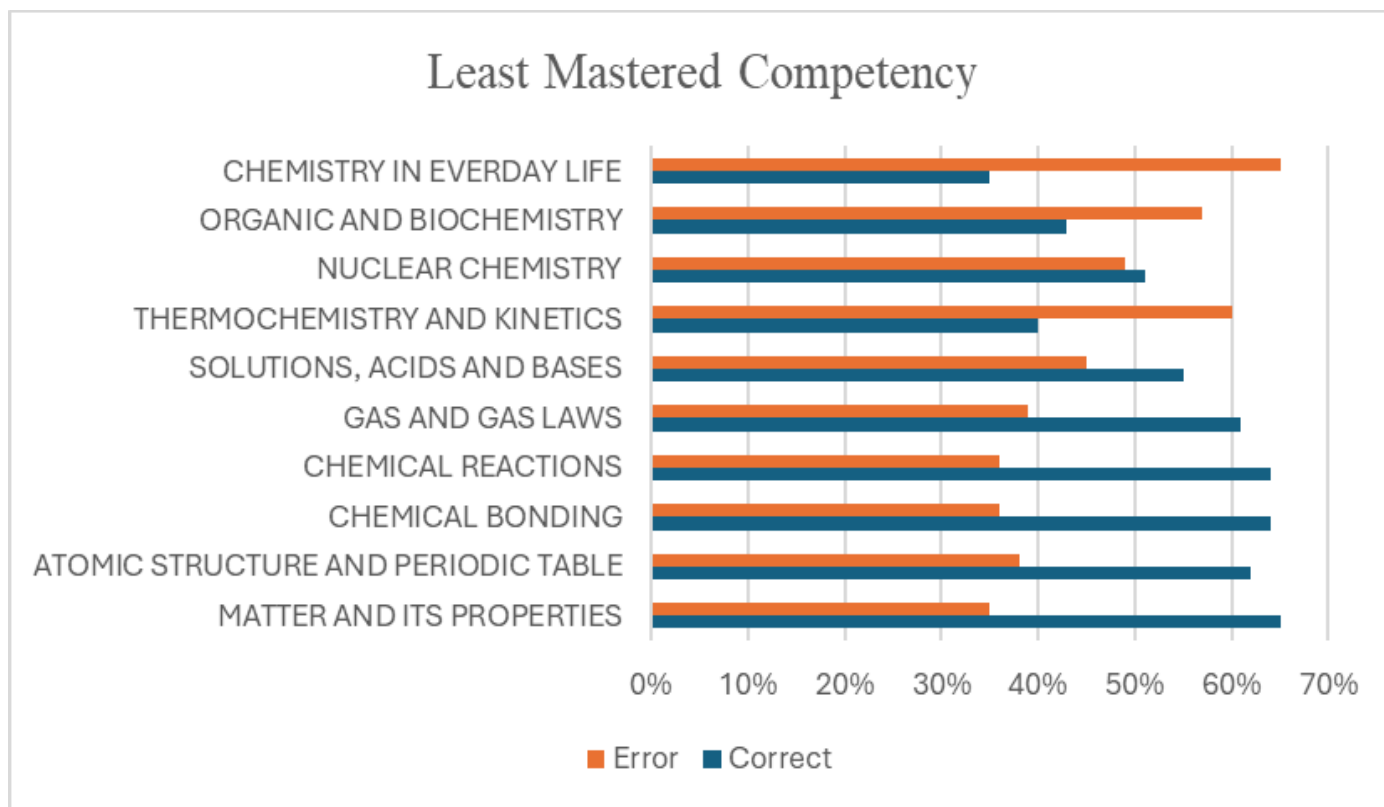


Figure 2 illustrates the distribution of correct and erroneous responses across General Chemistry competencies as measured by the PISA-Based Chemistry Questionnaire. The results clearly show variations in learners' mastery levels among the assessed topics. Chemistry in Everyday Life registered the lowest proportion of correct responses and the highest proportion of errors, indicating that it is the one of the least mastered competencies. This suggests that learners experienced significant difficulty in applying Chemistry concepts to real-life contexts, a core element of science literacy emphasized in the PISA framework.

Other competencies with relatively high proportions of erroneous responses include Thermochemistry and Kinetics, Organic and Biochemistry, Nuclear Chemistry, and Solutions, Acids, and Bases, indicating that these topics are least mastered. These areas involve abstract concepts, energy transformations, reaction dynamics, and molecular-level understanding, which may contribute to learners' conceptual difficulties.

In contrast, competencies such as Matter and Its Properties, Atomic Structure and Periodic Table, Chemical Bonding, Chemical Reactions, and Gas and Gas Laws showed higher proportions of correct responses compared to errors. These topics were classified as nearly mastered, suggesting that learners demonstrated better understanding of more foundational and structured Chemistry concepts.

Furthermore, the figure highlights a clear disparity in learners' mastery across Chemistry competencies, with greater difficulties observed in topics requiring higher-order thinking, abstraction, and real-life application. These findings underscore the need for targeted instructional interventions, contextualized teaching strategies, and enhanced learning resources to address the least mastered competencies and improve learners' overall performance in General Chemistry.

Table 4. Topic Ranking of the Least Mastered Competency Result

Rank	TOPIC	% Correct	Mastery Level
1	Chemistry in Everyday Life	35%	Not Mastered
2	Thermochemistry and Kinetics	40%	Least Mastered
3	Organic and Biochemistry	43%	Least Mastered
4	Nuclear Chemistry	49%	Least Mastered
5	Solutions, Acids and Bases	55%	Least Mastered
6	Gas and Gas Laws	61%	Nearly Mastered
7	Atomic Structure and Periodic Table	62%	Nearly Mastered
8	Chemical Reactions	64%	Nearly Mastered
9	Chemical Bonding	64%	Nearly Mastered
10	Matter and Its Properties	65%	Nearly Mastered

Legend: 80-100% = Mastered, 60-79% = Nearly Mastered, 40-59% = Least Mastered, 39% and below = Not Mastered

The result revealed that there is one Not Mastered Competency which is Chemistry in Everyday Life and four (4) Least Mastered Competency, which are Thermochemistry and Kinetics, Organic and Biochemistry, Nuclear Chemistry, and Solutions, Acids, and Bases. These competencies recorded the highest proportions of erroneous responses, indicating significant learning gaps among the respondents.

The results presented in Table 4 reveal that Chemistry in Everyday Life is the only competency classified as Not Mastered, with a mean percentage score of 35% correct. This indicates that learners experienced substantial difficulty in applying Chemistry concepts to real-life contexts, which is a core component of science literacy emphasized in the PISA Science Framework. The finding suggests that although learners may possess basic theoretical knowledge, they struggle to transfer and apply this knowledge to everyday situations. This difficulty may be attributed to instructional approaches that emphasize content recall rather than contextualized learning and problem-solving.

Moreover, four competencies were identified as Least Mastered, namely Thermochemistry and Kinetics (40%), Organic and Biochemistry (43%), Nuclear Chemistry (49%), and Solutions, Acids, and Bases (55%). These topics recorded relatively low percentages of correct responses, indicating persistent learning gaps in abstract, energy-related, and conceptually demanding Chemistry topics. The results suggest that learners encounter challenges in understanding microscopic processes, energy transformations, and the integration of Chemistry concepts across different contexts. Meanwhile, the remaining topics—Gas and Gas Laws (61%), Atomic Structure and Periodic Table (62%), Chemical Reactions (64%), Chemical Bonding (64%), and Matter and Its Properties (65%)—were classified as Nearly Mastered. This indicates that learners demonstrated a moderate level of understanding in these more foundational and structured Chemistry topics. Overall, the findings highlight a clear disparity in learners' mastery levels across General Chemistry competencies and underscore the need for targeted instructional interventions, contextualized teaching strategies, and enhanced learning resources to address the least mastered areas.

This study is supported by the findings of Orongan and Nabua (2020), who revealed that learners' performance in science, particularly in general chemistry, was characterized by a low mastery level, with many learners demonstrating the least mastery in key competencies. This highlights the need for improved instructional strategies to bridge knowledge gaps and enhance learning outcomes. Additionally, Sugano and Nabua (2020) emphasized that, in terms of instructional quality, their findings provide a comprehensive understanding of the current educational practices in chemistry instruction. This insight is invaluable, as it serves as a foundation for future educational reforms aimed at improving both teaching methodologies and student learning experiences in the field of chemistry.

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CONCLUSION

This study established the PISA-Based Chemistry Questionnaire (PISA-BCQ) as a valid, reliable, and standardized assessment tool for diagnosing General Chemistry competencies among senior high school learners. Expert validation results, acceptable internal consistency, and sound item difficulty and discrimination indices confirm the psychometric quality of the instrument and its alignment with the PISA Science Literacy Framework and the Most Essential Learning Competencies (MELCs). The implementation of the PISA-BCQ revealed generally low mastery levels among learners, with a large proportion failing to meet expected performance standards. Chemistry in Everyday Life emerged as a not mastered competency, while Thermochemistry and Kinetics, Organic and Biochemistry, Nuclear Chemistry, and Solutions, Acids, and Bases were identified as least mastered competencies, indicating learners' difficulties in applying Chemistry concepts to real-life contexts and in understanding abstract and conceptually demanding topics. These results led to the rejection of the null hypothesis, demonstrating significant variation in mastery levels across Chemistry competencies.

Therefore, the findings highlight the effectiveness of the PISA-BCQ in identifying learning gaps, providing meaningful diagnostic information, and supporting evidence-based instructional planning. The study reinforces the value of PISA-aligned assessment tools in improving Chemistry instruction and advancing learners' science literacy through targeted interventions and curriculum enhancement. These findings led to the rejection of the null hypothesis, confirming significant variations in mastery levels across Chemistry competencies. Based on the results, the study recommends the use of the PISA-BCQ as a diagnostic and formative assessment tool, the integration of PISA-aligned and contextualized tasks in Chemistry instruction, targeted instructional interventions for least mastered competencies, and further research involving broader samples and refined assessment items to enhance science literacy and instructional effectiveness.

ACKNOWLEDGEMENTS

The researcher expresses deep gratitude to all who supported the completion of this study. Foremost thanks go to God for strength and guidance, and to my adviser Dr. Edna Nabua for support and understanding. A Heartfelt thanks are also given to family and friends, including Mama Annie, Angel Ivy and to my late father, Papa Tirso. This is all for you, pa. To Kaly and Alden, and To Edward James, for their unwavering support, love, and encouragement specially to my toughest times this month. Lastly, special thanks to DOST-SEI for providing resources and opportunities. The study's success is credited to the collective effort of all who contributed to this journey.

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