Identifying Conceptual Gaps in Senior High School Chemistry Through a PISA-Aligned Assessment Framework

Joshua T. Tajures[1], Edna B. Nabua[2]

Department of Science and Mathematics Education Mindanao State University-Iligan Institute of Technology, Philippines

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ABSTRACT

Scientific literacy–oriented assessment has become a central goal of contemporary science education; however, Chemistry assessment practices in many senior high school contexts remain largely recall-based and offer limited diagnostic value for identifying students' conceptual learning gaps. Within the Philippine setting, locally developed assessment tools aligned with the Programme for International Student Assessment (PISA) Science Framework remain scarce. This study examined the Chemistry mastery levels of Grade 12 students using a PISAaligned assessment instrument and identified least mastered content areas to inform instructional planning. Using a descriptive research design, data were gathered from Grade 12 students through a researcher-developed, PISAaligned Chemistry questionnaire. Analysis of students' performance revealed that a majority did not meet expected proficiency levels, indicating substantial learning gaps. Topic-level results showed that Nuclear Chemistry, Chemical Reactions, and Atomic Structure were the least mastered areas, while performance was comparatively stronger in Chemistry in Everyday Life, suggesting greater understanding in applied and contextualized content. The findings highlight the value of PISA-aligned assessments as diagnostic tools for revealing topic-specific learning gaps and supporting evidence-informed instructional decisions. The study underscores the need for targeted instructional interventions and assessment practices that prioritize conceptual understanding and scientific literacy, particularly in abstract and conceptually demanding areas of Chemistry

Keywords: Chemistry performance, PISA-aligned assessment, least mastered topics

INTODUCTION

Science education has increasingly emphasized the development of scientific literacy, defined as learners' capacity to apply scientific knowledge, reason critically with evidence, and make informed decisions in authentic, real-world contexts (Tasquier et al., 2022). This orientation is strongly reflected in the Programme for International Student Assessment (PISA), which conceptualizes scientific literacy through students' abilities to explain phenomena scientifically, evaluate and design scientific investigations, and interpret data and evidence

(Teig, 2023). Such competencies align with the broader educational objectives articulated in Sustainable Development Goal 4 (SDG 4), which seeks to ensure inclusive and equitable quality education by prioritizing meaningful learning outcomes and the acquisition of competencies essential for lifelong learning and societal participation (Broeck et al., 2024).

Despite this global shift toward scientific literacy, chemistry education continues to face persistent challenges, largely due to the abstract and conceptually demanding nature of chemical knowledge. These challenges are further compounded by the continued reliance on traditional assessment practices that prioritize factual recall and algorithmic problem solving over higher-order reasoning and contextual application (Vo & Simmie, 2024). Consequently, such assessment approaches often fail to provide sufficient diagnostic information regarding students' conceptual understanding and do not effectively identify specific chemistry domains in which learning gaps persist (Taglorin et al., 2025). Within the Philippine senior high school context, analyses of students' performance in international large-scale assessments have underscored the urgent need for competency-based, internationally benchmarked assessment tools that remain aligned with national curriculum standards and responsive to learners' contextual realities (Oliveri & Lawless, 2018).

This gap in the literature underscores the need for contextually responsive, standards-aligned diagnostic assessments that go beyond overall achievement reporting and provide actionable evidence for instructional improvement. In particular, there is a lack of empirical studies that systematically identify least mastered Chemistry topics among senior high school students using a locally validated, PISA-aligned assessment framework.

In response to these concerns and in support of SDG 4, this study developed a PISA-aligned Chemistry assessment instrument to evaluate the mastery levels of Grade 12 students. Establishing students' levels of mastery and identifying least mastered content areas through a scientifically grounded and psychometrically sound assessment tool are critical for informing instructional planning, targeted remediation, and curriculum refinement. Accordingly, the present study aimed to determine the Chemistry mastery levels of Grade 12 students using a PISA-aligned questionnaire, with particular emphasis on identifying least mastered topics as a basis for evidence-informed instructional and curricular improvement.

Research Objectives

The primary objective of this study was to determine the mastery level of Grade 12 students in Chemistry using an assessment instrument aligned with the Programme for International Student Assessment (PISA) Science Framework. Specifically, the study aimed to develop a 50-item multiple-choice Chemistry questionnaire that reflects the scientific literacy competencies emphasized in the PISA framework and is appropriate for the Grade 12 curriculum. In addition, the study sought to describe students' performance levels in Chemistry based on their test scores and to identify the least mastered Chemistry topics as indicated by students' responses. These objectives were intended to provide empirical evidence that could inform instructional planning, remediation strategies, and curriculum enhancement.

METHODOLOGY

Research Design

This study employed a descriptive research design to examine the mastery level of Grade 12 students in Chemistry using a PISA-aligned assessment instrument. The descriptive approach was deemed appropriate as the study focused on systematically describing and analyzing students' current levels of mastery across selected Chemistry content areas without manipulating variables or implementing instructional interventions. This design facilitated the objective collection and quantitative analysis of students' test responses, thereby enabling the identification of overall performance trends and least mastered topics. Through this approach, the study generated empirical data that serve as a sound basis for evidence-informed instructional planning and pedagogical improvement in Chemistry education.

Participants

The participants comprised 107 Grade 12 students enrolled in a Chemistry course at the time of data collection. A purposive sampling technique was employed to ensure alignment between the respondents and the Grade 12 Chemistry curriculum. The sample size was considered adequate for the study's diagnostic and descriptive objectives, including item-level analysis and topic-based mastery classification, rather than population-level inference. In educational assessment research, samples of this size are sufficient to yield stable estimates of performance patterns and variability across content domains, supporting valid identification of least mastered topics. Given the study's diagnostic intent, the sample was appropriate for achieving internal validity and analytical precision within the instructional context.

Research Instrument

The primary data-gathering instrument was a researcher-developed, PISA-aligned Chemistry questionnaire consisting of 50 multiple-choice items. The instrument was designed to assess students' scientific literacy and conceptual mastery of selected Grade 12 Chemistry topics by situating questions within real-world contexts. Each item was aligned with the core competencies of the PISA Science Framework, namely explaining phenomena scientifically, evaluating and designing scientific inquiry, and interpreting data and evidence

scientifically. Emphasis was placed on measuring students' ability to apply Chemistry concepts rather than merely recall information. Prior to administration, the instrument underwent expert validation to ensure content relevance, clarity, and alignment with both the PISA framework and the national curriculum standards.

Table 1 Descriptors for Performance Levels

Descriptor	Score Range
Outstanding	90–100
Very Satisfactory	85–89
Satisfactory	80–84
Fairly Satisfactory	75–79
Did Not Meet Expectations	74 and below

Note. Performance levels were classified based on the institutional grading scale. Scores of 75 and above were interpreted as **Passed**, while scores below 75 were interpreted as **Failed**.

The performance descriptors used to classify students' achievement levels in the Chemistry assessment, based on their corresponding percentage scores, are presented in Table 1. The grading scale adopts a standardsbased framework, wherein progressively higher score ranges reflect increasing levels of conceptual mastery. Students who obtained percentage scores ranging from 90 to 100 were classified as *Outstanding*, signifying a high degree of conceptual understanding and proficiency in applying Chemistry concepts. Those who scored within the *Very Satisfactory* (85–89) and *Satisfactory* (80–84) ranges demonstrated adequate to strong mastery of the assessed competencies.

Students who achieved scores between 75 and 79 were categorized as *Fairly Satisfactory*, indicating minimum acceptable performance relative to institutional and curricular standards. In contrast, students who obtained scores below 75 were classified as *Did Not Meet Expectations*, reflecting insufficient mastery of essential Chemistry competencies. This level of performance suggests the presence of substantive learning gaps that may impede students' academic progression and underscores the need for targeted instructional support and systematic remediation. Consistent with principles of standards-based assessment, the application of clearly articulated performance descriptors enhances the interpretability and instructional utility of assessment results and provides a robust basis for identifying learners who require additional academic intervention (Guskey, 2015).

Table 2 Mastery Levels and Percentage Equivalents Used in the Study

Mastery Level	Percentage Equivalent
Mastered	80–100
Nearly Mastered	75–79
Least Mastered	51–74
Not Mastered	50 and below

The mastery levels and percentage equivalents shown in Table 2 were used to interpret students' mean percentage scores in Chemistry. After computing the mean percentage score for each topic, the scores were classified into one of four mastery levels—Mastered, Nearly Mastered, Least Mastered, or Not Mastered. This classification provided a clear and consistent basis for evaluating students' achievement and for identifying Chemistry topics that require further instructional emphasis.

Data Collection Procedure

Prior to data collection, the PISA-aligned Chemistry questionnaire was systematically developed based on the PISA Science Framework and the identified Grade 12 Chemistry competencies. Item construction involved careful alignment with the PISA cognitive domains to ensure adequate content representation and conceptual coherence. To further strengthen the quality of the instrument, a readability assessment was conducted to evaluate the clarity, comprehensibility, and linguistic appropriateness of the test items for the target respondents. This process ensured that the language used in the questionnaire was accessible to Grade 12 students and minimized potential misinterpretation arising from excessive linguistic complexity.

Following content validation and readability evaluation, the instrument was revised accordingly. Formal permission to conduct the study was then obtained from the school authorities. Upon approval, the finalized PISA-aligned Chemistry questionnaire was administered to the respondents during a scheduled testing session to maintain standardized administration conditions. Prior to test administration, clear and uniform instructions were provided to all participants. After completion, students' responses were collected, reviewed for completeness, and scored using the established scoring protocol. The resulting data were systematically recorded, coded, and organized in preparation for subsequent statistical analysis.

Data Analysis

Content validity of the PISA-aligned Chemistry questionnaire was established through expert evaluation using the Content Validity Index (CVI), while internal consistency reliability was examined using Cronbach's alpha, KR-20, and KR-21. Item quality was further assessed through difficulty and discrimination indices, with revisions made prior to final administration when necessary.

Students' performance was analyzed using frequency and percentage distributions and mean percentage scores (MPS) at both overall and topic levels. Mean percentage scores were used to enable standardized interpretation across Chemistry domains with varying item counts and to align results with institutional grading practices. Performance was classified using predefined mastery thresholds, grounded in standards-based assessment principles, to distinguish mastery, near-mastery, limited mastery, and non-mastery. Topic-level mastery was determined by aggregating item performance within each content area, strengthening the diagnostic validity of the findings and supporting evidence-based instructional recommendations.

Ethical Considerations

The study adhered strictly to established ethical standards to safeguard the rights, welfare, and confidentiality of all participants. Participation was voluntary, and informed consent was obtained after providing a clear explanation of the study's purpose, procedures, potential benefits, and minimal associated risks. Participants were informed of their right to withdraw from the study at any point without penalty. All data were treated with strict confidentiality, securely stored, and reported only in aggregated form to prevent the identification of individual respondents. The conduct of the study was guided by the principles of beneficence, respect for persons, and justice, in accordance with the National Ethical Guidelines for Health and HealthRelated Research (2023) and the Data Privacy Act of 2012 (Republic Act No. 10173), ensuring ethical and responsible research practice throughout the research process.

RESULTS AND DISCUSSION

Development of the PISA-Aligned Chemistry Questionnaire

The Chemistry questionnaire was developed in accordance with the competencies specified in the Programme for International Student Assessment (PISA) Science Framework, namely explaining phenomena scientifically, evaluating and designing scientific inquiry, and interpreting data and evidence scientifically. Chemistry content was drawn from the Grade 12 curriculum and situated within authentic, real-life contexts to ensure curricular relevance and alignment with the overarching objectives of scientific literacy.

To ensure systematic coverage of content and competencies, a table of specifications was employed to distribute test items across selected Chemistry topics and PISA competency domains. The instrument comprised multiple-choice items designed to assess students' ability to apply Chemistry concepts in contextualized situations rather than rely solely on the recall of discrete factual knowledge. Prior to expert validation, the questionnaire underwent a readability assessment to evaluate the clarity, comprehensibility, and linguistic appropriateness of the test items for Grade 12 learners. This process ensured that the language level of the instrument was suitable for the target population and minimized potential misinterpretation due to linguistic complexity.

Following the readability assessment, the instrument was subjected to expert validation to examine content relevance, conceptual accuracy, clarity of expression, and alignment with both the PISA framework and national curriculum standards. Revisions were incorporated based on the experts' recommendations, resulting in a

finalized 50-item PISA-aligned Chemistry questionnaire deemed appropriate for assessing students' mastery levels and scientific literacy competencies at the Grade 12 level.

Table 3 Content Validity Ratings of the PISA-Aligned Chemistry Questionnaire by Expert Validators

Criteria	Expert 1	Expert 2	Expert 3	*M*	Description
Content	3.58	3.78	4.00	3.79	Excellent
Clarity of wording	3.58	3.78	3.96	3.77	Excellent
Appropriateness of difficulty	3.54	4.00	4.00	3.85	Excellent
Quality of distractors	3.54	4.00	3.96	3.83	Excellent
Formality and consistency	3.58	4.00	4.00	3.86	Excellent
Alignment with learning objectives	3.64	3.78	4.00	3.81	Excellent

Table 3 presents the results of the content validity evaluation of the PISA-aligned Chemistry questionnaire as assessed by three expert validators. The instrument was evaluated across six criteria—content relevance, clarity of wording, appropriateness of difficulty, quality of distractors, formality and consistency, and alignment with learning objectives—using a four-point Likert scale.

The criterion *content relevance* obtained a mean rating of $M = 3.79$, which was interpreted as *Excellent*, indicating that the scope, accuracy, and coverage of the questionnaire items were appropriate for assessing Chemistry concepts aligned with the PISA Science Framework. Similarly, *clarity of wording* yielded a mean rating of $M = 3.77$, suggesting that the test items were clearly articulated and readily comprehensible to the intended respondents.

The criteria *appropriateness of difficulty* ($M = 3.85$) and *quality of distractors* ($M = 3.83$) were likewise rated as *Excellent*, reflecting that the level of item difficulty was suitable for Grade 12 learners and that the distractors were plausible and functioned effectively in discriminating between correct and incorrect responses. In addition, *formality and consistency* received the highest mean rating ($M = 3.86$), indicating uniform item construction and adherence to appropriate academic tone and formatting conventions.

Finally, the criterion *alignment with learning objectives* obtained a mean rating of $M = 3.81$, demonstrating that the questionnaire items were well aligned with the intended Chemistry learning outcomes. Taken together, the consistently high mean ratings across all evaluated criteria provide strong empirical evidence of the content validity of the PISA-aligned Chemistry questionnaire, supporting its suitability for assessing students' mastery levels and for identifying least mastered Chemistry content areas.

Table 4 Reliability Coefficients of the PISA-Aligned Chemistry Questionnaire Table 4 presents the reliability coefficients of the PISA-aligned

Reliability Measure	Coefficient Value	Interpretation
Kuder–Richardson Formula 20 (KR-20)	0.8269	Reliable
Kuder–Richardson Formula 21 (KR-21)	0.8052	Reliable
Cronbach's Coefficient Alpha	0.8256	Reliable

Chemistry questionnaire as estimated using the Kuder–Richardson Formula 20 (KR-20), Kuder–Richardson Formula 21 (KR-21), and Cronbach's coefficient alpha. The KR-20 coefficient yielded a value of 0.8269, indicating a high degree of internal consistency among the dichotomously scored items. Consistently, the KR-21 coefficient produced a reliability estimate of 0.8052, further supporting the stability and consistency of the instrument.

To provide additional evidence of internal consistency, Cronbach's coefficient alpha was also computed. The obtained alpha value of 0.8256 falls within the range generally interpreted as acceptable to high reliability for educational measurement. The convergence of these three reliability indices provides robust evidence that the questionnaire items consistently measure the same underlying construct, namely students' mastery of Chemistry concepts aligned with the PISA Science Framework.

Overall, the reliability findings indicate that the PISA-aligned Chemistry questionnaire meets established psychometric standards and is sufficiently reliable for assessing students' Chemistry performance and for identifying least mastered content areas. These results indicate that the PISA-aligned Chemistry questionnaire is psychometrically sound and appropriate for assessing students' mastery of Chemistry concepts, providing a reliable basis for identifying the least mastered topics among Grade 12 learners.

Performance Level of Students in Chemistry

Students' performance was analyzed based on score distribution, grading scale, and corresponding performance interpretation. The results describe the respondents' overall level of achievement and determine whether they met the institutional passing standards.

Table 5 Distribution of Students According to Score Range, Grading Scale, and Performance Interpretation

Score Range	Frequency	Descriptor	Interpretation
45–50	0	Outstanding	Passed
43–44	2	Very Satisfactory	Passed
40–42	5	Satisfactory	Passed
38–39	6	Fairly Satisfactory	Passed
0–37	94	Did Not Meet Expectations	Failed
Total	**107**	—	—

Note. Total number of respondents (N = 107). Scores of 75 and above were interpreted as *Passed*, while scores below 75 were interpreted as *Failed*, following the institutional grading policy.

Table 5 presents the distribution of students according to score ranges, performance descriptors, and corresponding interpretations. Among the 107 respondents, the majority (n = 94) obtained scores within the 0–37 range, classified as *Did Not Meet Expectations* and interpreted as *Failed*. This finding indicates that most students were unable to achieve the minimum proficiency level established by institutional grading standards.

A smaller proportion of students attained passing scores. Six respondents fell within the *Fairly Satisfactory* range (38–39), five were classified as *Satisfactory* (40–42), and two achieved *Very Satisfactory* ratings (43–44). Notably, no students attained scores within the *Outstanding* range (45–50). These performancelevel distributions suggest that a substantial proportion of learners are operating at or below the minimum acceptable level of mastery in Chemistry, particularly in conceptually demanding areas.

Results indicated that a majority of Grade 12 students did not attain expected proficiency levels in Chemistry, with most classified as Did Not Meet Expectations. Interpreted through the lens of scientific literacy and cognitive demand, this pattern suggests limited ability to integrate macroscopic, submicroscopic, and symbolic representations—an essential requirement for higher-order reasoning in Chemistry. The findings imply that many students rely on fragmented or procedural knowledge, which is insufficient for explaining phenomena, interpreting data, or applying concepts in unfamiliar contexts emphasized in PISA-aligned assessments. Consistent with local and international studies, this underperformance reflects the limitations of recall-oriented assessment practices, which may obscure deeper conceptual difficulties. The present study reinforces evidence that literacy-oriented assessments more effectively reveal disparities in conceptual understanding, even within a single instructional context.

Least Mastered Chemistry Topics

The distribution indicates a generally low level of academic performance among the respondents, with a substantial proportion failing to achieve the expected standards. These findings underscore the presence of significant learning gaps and emphasize the need for targeted instructional support and remediation to enhance students' conceptual understanding and overall academic performance.

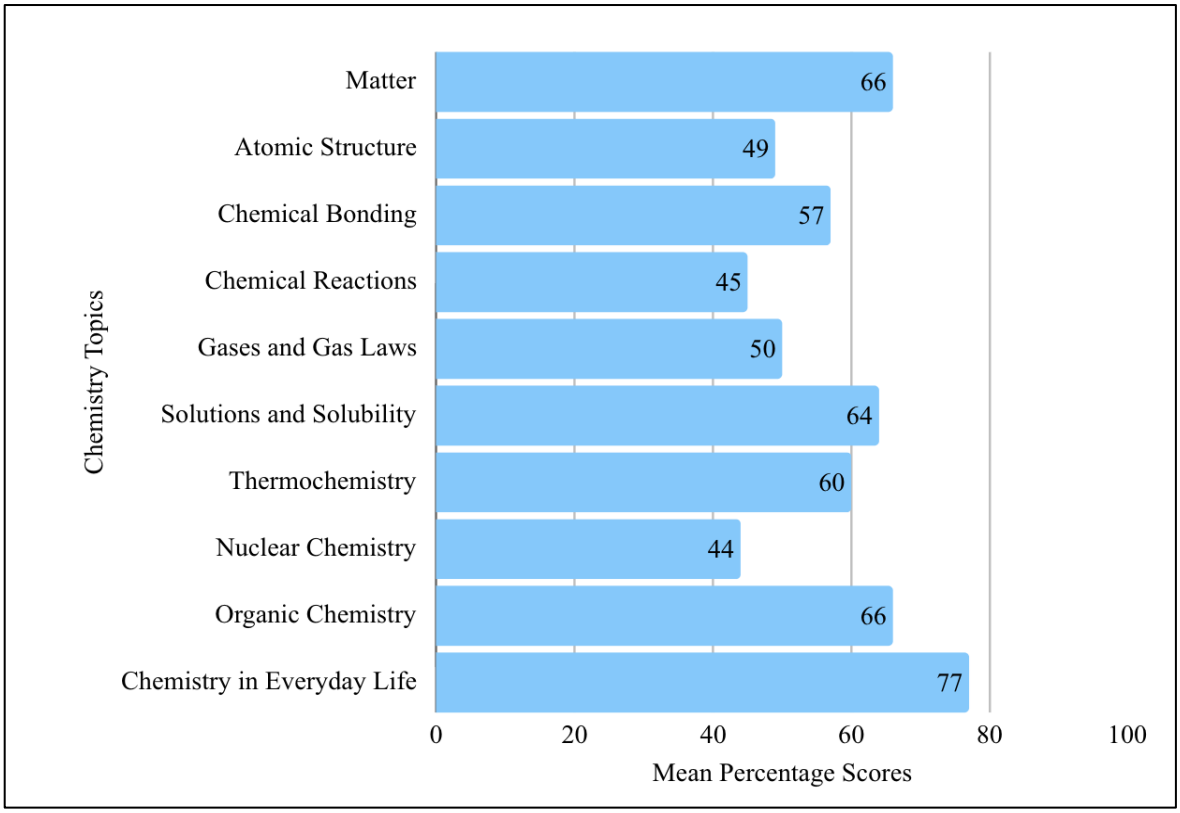

Figure 1 Mean Percentage Scores of Chemistry Topics

Chemistry both obtained mean scores of 66%, reflecting relatively higher performance relative to other content areas.

Moderate mean scores were observed in *Solutions and Solubility* (64%) and *Thermochemistry* (60%), suggesting partial understanding with residual learning gaps. *Chemical Bonding* also fell within this range, with a mean score of 57%, indicating that students possessed basic knowledge but struggled with more complex applications.

In contrast, the lowest mean scores were observed in *Gases and Gas Laws* (50%), *Atomic Structure* (49%), *Chemical Reactions* (45%), and *Nuclear Chemistry* (44%). These results identify the weakest areas of student performance, highlighting limited conceptual mastery and increased difficulty in comprehending abstract principles, theoretical models, and process-based phenomena. The findings underscore the need for targeted instructional strategies to strengthen understanding in these challenging domains.

Topic-Based Analysis

Table 6 Ranked Chemistry Topics Based on Mean Percentage Scores and Mastery Levels

Topic	Mean % Score	Mastery Level	Rank
Nuclear Chemistry	44	Not Mastered	1
Chemical Reactions	45	Not Mastered	2
Atomic Structure	49	Not Mastered	3
Gases and Gas Laws	50	Not Mastered	4
Chemical Bonding	57	Least Mastered	5
Thermochemistry	60	Least Mastered	6
Solutions and Solubility	64	Least Mastered	7
Matter and Its Properties	66	Least Mastered	8
Organic Chemistry	66	Least Mastered	8
Chemistry in Everyday Life	77	Nearly Mastered	9

A topic-based analysis was conducted by categorizing the test items according to their designated Chemistry topics and calculating the mean percentage score for each category. Table 6 presents the ranking of topics based

on students' mean scores, providing a systematic identification of the least mastered areas using the PISA-aligned questionnaire. Topics were ranked from lowest to highest mean percentage score, with highest ranks reflecting lower levels of mastery.

The results indicate that *Nuclear Chemistry* was the least mastered topic, obtaining the lowest mean percentage score (M = 44; Rank 1) and classified as *Not Mastered*. This was followed by *Chemical Reactions* (M = 45; Rank 2) and *Atomic Structure* (M = 49; Rank 3), which were also categorized as *Not Mastered*, revealing substantial learning gaps in these foundational and conceptually demanding areas. *Gases and Gas Laws* ranked fourth (M = 50), further underscoring students' difficulties with abstract concepts involving particle behavior and quantitative relationships.

Topics ranked fifth to eighth were classified as *Least Mastered*, including *Chemical Bonding* (M = 57; Rank 5), *Thermochemistry* (M = 60; Rank 6), *Solutions and Solubility* (M = 64; Rank 7), and *Matter and Its Properties* (M = 66; Rank 8). *Organic Chemistry* also obtained a mean score of 66, sharing the same rank and indicating comparable mastery levels. Although these topics were not classified as *Not Mastered*, the results suggest that students' understanding remains insufficient for consistent mastery-level performance. In contrast, *Chemistry in Everyday Life* achieved the highest mean score (M = 77; Rank 9) and was classified as *Nearly Mastered*, reflecting stronger performance in applied and contextualized Chemistry concepts. Collectively, these findings identify *Nuclear Chemistry*, *Chemical Reactions*, and *Atomic Structure* as priority areas for instructional intervention and provide an empirical basis for targeted teaching strategies and remedial activities.

Topic-level analysis identified Nuclear Chemistry, Chemical Reactions, and Atomic Structure as the least mastered domains. These topics are highly abstract, theoretically dense, and reliant on symbolic representations, imposing substantial cognitive load when instructional scaffolding is insufficient. Limited instructional time and peripheral curricular placement may further contribute to weak conceptual coherence, particularly in Nuclear Chemistry. In contrast, stronger performance in Chemistry in Everyday Life highlights the instructional value of contextualization. Consistent with context-based learning theory, embedding concepts in real-world situations appears to enhance understanding and transfer. These results align with comparative studies showing superior performance on applied tasks relative to abstract, decontextualized problems, illustrating how topic characteristics interact with assessment design to produce differentiated mastery patterns.

Pedagogical and Assessment Implications

The findings underscore the need for targeted, concept-focused instructional interventions, particularly for abstract Chemistry domains. Instructional strategies such as multiple-representation teaching, guided inquiry, visualization, and formative feedback have been shown to support students in bridging macroscopic, submicroscopic, and symbolic representations, thereby strengthening conceptual understanding and higher-order reasoning (Vo & Simmie, 2024). Additionally, the results support integrating PISA-aligned diagnostic assessments into classroom practice, as these tools provide actionable insights into students' reasoning processes and conceptual weaknesses beyond what traditional summative assessments typically reveal. The contrast between performance in abstract and applied topics further suggests that context-based and problem-centered pedagogies can enhance conceptual understanding and scientific literacy by situating learning in meaningful, real-world contexts. Overall, the study demonstrates the value of locally developed, PISA-aligned assessments as diagnostic tools that inform instructional innovation and assessment reform in senior high school Chemistry.

CONCLUSION

This study developed and validated a 50-item PISA-aligned Chemistry questionnaire to examine Grade 12 students' mastery levels and identify least mastered content areas. The instrument demonstrated sound psychometric properties and functioned effectively as a diagnostic tool. Results showed that most students did not meet expected proficiency standards, with notable learning gaps in Nuclear Chemistry, Chemical Reactions, and Atomic Structure, while stronger performance was observed in applied, real-life Chemistry contexts.

Several limitations should be acknowledged. The use of a single-school, purposive sample limits generalizability, and the reliance on a multiple-choice format may not fully capture students' reasoning or misconceptions. In addition, the descriptive design precludes causal interpretation of the factors underlying the observed learning

gaps. Future research should involve larger and more diverse samples, employ mixed-methods approaches to explore students' reasoning processes, and examine the effectiveness of targeted instructional interventions and formative, PISA-aligned assessment practices.

Practically, the findings underscore the value of diagnostic, literacy-oriented assessments in guiding targeted instruction, particularly in abstract Chemistry domains. For policymakers and curriculum planners, the results support assessment reform and professional development initiatives that align classroom practices with scientific literacy goals. Overall, the study provides empirical evidence to inform instructional improvement and strengthen Chemistry education through contextually responsive, standards-aligned assessment.

RECOMMENDATION

Based on the findings and conclusions of the study, the following recommendations are proposed:

1. Teachers are encouraged to implement targeted instructional strategies for least mastered topics, particularly Nuclear Chemistry, Chemical Reactions, and Atomic Structure. The use of visual aids, simulations, inquiry-based activities, comics, and game-based learning materials may help improve students' conceptual understanding of abstract Chemistry concepts.
2. The identified least mastered topics may be given greater emphasis in curriculum planning, instructional time allocation, and enrichment or remediation programs. Incorporating PISA-aligned tasks and real-world problem-solving activities may help strengthen students' scientific literacy.
3. Students are encouraged to engage in supplementary learning activities such as interactive modules, practice problems, and collaborative learning experiences to enhance their understanding of challenging Chemistry topics.
4. Future studies may expand the scope by including larger and more diverse samples, comparing mastery levels across schools or regions, or examining the effectiveness of specific instructional interventions designed to address the identified least mastered topics.
5. The validated PISA-aligned Chemistry questionnaire may be utilized by schools and educators as a diagnostic assessment tool to monitor students' mastery levels and guide data-driven instructional decisions.

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