Development and Preliminary Validation of CHEM-LENS: A Diagnostic Instrument for Identifying Senior High School Chemistry Learning Needs

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ABSTRACT

Instructional planning in Senior High School chemistry is frequently informed by summative assessment outcomes, which offer limited diagnostic insight into students' topic-specific learning needs. This study reports the development and preliminary validation of CHEM-LENS (Chemistry Learning Needs Survey), a curriculum-aligned diagnostic instrument designed to identify perceived learning difficulties across major chemistry domains. Employing a quantitative descriptive research design, CHEM-LENS was developed through a staged, theory-informed process encompassing curriculum-based item construction, readability evaluation, expert content validation, pilot testing, item analysis, and estimation of internal consistency reliability. The finalized 50-item instrument was administered to Senior High School students (n = 80), with a separate pilot sample (n = 50). Findings indicated acceptable preliminary measurement quality, including strong expert-rated content validity, satisfactory item functioning, and good internal consistency reliability (Cronbach's α = .83). Results of the needs assessment revealed differentiated patterns of chemistry learning difficulty, with thermochemistry, chemical reactions, chemical bonding, and atomic structure emerging as high-priority learning need areas. In contrast, topics grounded in foundational concepts and real-life applications were perceived as less challenging. Collectively, these findings suggest that CHEM-LENS demonstrates adequate preliminary quality for diagnostic use and holds promise for supporting data-informed instructional planning in Senior High School chemistry. Further psychometric validation is recommended to strengthen its measurement properties and applicability across diverse educational contexts.

Keywords: Chemistry Education, Instrument, Needs Assessment

INTRODUCTION

Chemistry is a core component of the Senior High School curriculum and plays a pivotal role in cultivating students' scientific literacy, analytical reasoning, and understanding of matter and its transformations (Farillon, 2022). As a foundational science discipline, chemistry equips learners with conceptual tools necessary for interpreting natural phenomena and addressing real-world problems. However, despite its curricular importance, extensive research has consistently documented persistent learning difficulties among secondary-level students, particularly in topics that demand abstract reasoning, symbolic representation, and quantitative problem solving (Barcelo, 2024). These difficulties often manifest as fragmented conceptual understanding and an excessive reliance on rote procedural strategies, indicating students' challenges in integrating macroscopic observations, submicroscopic explanations, and symbolic representations of chemical phenomena (Djaen & Rahayu, 2021).

Instructional decision-making in chemistry classrooms is commonly guided by summative assessment outcomes, such as examination scores and final grades. While such measures are useful for evaluating overall achievement, they provide limited diagnostic insight into students' specific conceptual strengths and weaknesses across content domains (Rokhim et al., 2024). As a result, teachers may lack actionable information needed to design targeted instructional interventions. Contemporary assessment literature increasingly underscores the importance of diagnostic and needs-based assessment approaches that systematically identify gaps between

intended learning outcomes and students' actual understanding, thereby enabling more responsive and data-informed instruction (Ridlo et al., 2024).

Although needs assessment has been recognized as an effective strategy for uncovering learning gaps in chemistry, the availability of systematically developed, curriculum-aligned, and context-sensitive diagnostic instruments for Senior High School chemistry remains limited, particularly in developing educational contexts such as the Philippines (Barcelo, 2024). Many existing diagnostic tools are narrowly focused, technically complex, or impractical for routine classroom use, thereby constraining their utility for everyday instructional planning (Khoiriyah et al., 2025). Addressing this gap, the present study focused on the development and preliminary validation of the Chemistry Learning Needs Survey (CHEM-LENS), a curriculum-aligned diagnostic instrument designed to identify Senior High School students' learning needs across major chemistry domains. Specifically, the study sought to establish foundational evidence of the instrument's quality in terms of readability, content validity, item functioning, and internal consistency reliability, and to demonstrate its application in identifying priority learning needs to support data-informed instructional planning (Putica, 2022; Ye & Qian, 2024).

METHODOLOGY

Research Design

This study employed a quantitative descriptive research design using an instrument development and preliminary validation approach. This design was appropriate for establishing initial evidence of the measurement quality of CHEM-LENS and for generating a descriptive profile of students' perceived learning needs across curriculum-aligned chemistry topics. Data were collected using a cross-sectional survey administered at a single point in time. Consistent with early-stage instrument development, the study did not seek to test causal relationships or evaluate instructional interventions; rather, it focused on diagnostic assessment and exploratory validation to support future refinement and broader application of the instrument.

Research Setting and Participants

The study was conducted in a Senior High School implementing the nationally prescribed chemistry curriculum, thereby ensuring alignment between classroom instruction and the competencies targeted by CHEM-LENS. A total of 130 Senior High School students enrolled in chemistry participated in the study. Of these, 50 students were involved in pilot testing, while 80 students participated in the final administration of the instrument.

A non-probability convenience sampling technique was utilized, wherein students who were present during the data collection period and who provided informed consent were invited to participate. This sampling approach was deemed appropriate for a micro-level study focused on preliminary instrument validation. Although the sample size was adequate for establishing initial evidence of readability, item functioning, and internal consistency reliability, the findings were interpreted within the context of the participating school and were not intended for broad generalization.

Research Instrument

The primary instrument used in this study was CHEM-LENS (Chemistry Learning Needs Survey), a researcher-developed diagnostic questionnaire composed of multiple-choice test items designed to identify Senior High School students' learning needs across curriculum-aligned chemistry topics. The instrument consisted of 50 scenario-based multiple-choice items distributed across ten major chemistry domains, with five items allocated to each domain.

Each item presented a contextualized chemistry scenario followed by a question assessing students' conceptual understanding of the targeted competency. Response options included one scientifically correct answer and several distractors deliberately constructed to reflect common misconceptions or partial understandings documented in the chemistry education literature. Students' response patterns were analyzed at both the item and domain levels to identify areas of conceptual difficulty and priority learning needs.

The development of CHEM-LENS was guided by competencies specified in the Senior High School chemistry curriculum and informed by empirical studies on chemistry learning difficulties and diagnostic assessment practices. The instrument underwent a staged development and preliminary validation process that included item construction, readability assessment, expert content validation, pilot testing, item analysis, and estimation of internal consistency reliability prior to final administration. Collectively, these procedures provided foundational evidence supporting the instrument's suitability for diagnostic and exploratory use in identifying chemistry learning needs.

Data Collection Procedure

Data collection followed a systematic, staged procedure consistent with best practices in educational instrument development. Initial item construction was grounded in the Senior High School chemistry curriculum and supported by relevant literature on common student misconceptions and learning challenges. The draft version of CHEM-LENS underwent readability evaluation and expert-based content validation, after which revisions were made to enhance clarity, relevance, and curricular alignment.

Subsequently, pilot testing was conducted with a group of Senior High School students who were not included in the final sample. Data obtained from the pilot phase were used exclusively for formative purposes, informing revisions to item wording, structure, and distractor quality. Following refinement, the finalized version of CHEM-LENS was administered to the main group of participants during regular class periods using standardized instructions. Students were allotted sufficient time to complete the instrument, after which completed questionnaires were collected immediately. All responses were screened for completeness and accuracy before being coded and prepared for statistical analysis.

Ethical Consideration

Ethical standards for educational research were observed throughout the study. Participation was voluntary, informed consent was obtained from all participants, and confidentiality was ensured through the anonymization of responses. The data collected were used solely for academic and research purposes. The author declares no potential conflicts of interest with respect to the conduct and reporting of this study.

RESULTS AND DISCUSSION

Preliminary Validation of CHEM-LENS

To address the preliminary validation of CHEM-LENS, multiple sources of evidence related to readability, content validity, item functioning, and internal consistency reliability were examined and synthesized to provide an overall evaluation of the instrument's measurement quality. These indicators were derived from the staged development, pilot testing, and item analysis procedures employed in the study. Table 1 presents a summary of the key validation results along with their corresponding interpretations, offering an integrated overview of the instrument's strengths and areas for refinement in supporting diagnostic assessment of Senior High School chemistry learning needs.

Table 1. Summary of Preliminary Validation Results for CHEM-LENS

Validation Aspect	Indicator	Result	Interpretation
Readability	Linguistic appropriateness for SHS students	**Appropriate**	Items suitable for target population
Content validity	Mean expert rating	**M = 3.65**	High relevance and alignment
Item quality	Item–total correlation range	**r = .21–.61**	Acceptable to good item functioning
Reliability	Internal consistency	**Cronbach's α = .83**	Good internal consistency

The consolidated validation results presented in Table 1 provide preliminary empirical evidence that CHEM-LENS possesses acceptable measurement quality for diagnostic application in Senior High School chemistry. Rather than interpreting validation indices independently, the convergence of evidence across content relevance, item functioning, and internal consistency suggests structural coherence within the instrument, a characteristic emphasized in staged and theory-driven models of instrument development (DeVellis, 2017).

The strong expert-based content validity observed in this study aligns with prior research in chemistry education that identifies expert judgment as a critical mechanism for ensuring curricular alignment and comprehensive conceptual coverage in diagnostic assessments (Witkin & Altschuld, 1995; Mi & Ye, 2023; Barcelo, 2024). Within chemistry education, expert validation is particularly salient for abstract and representationally demanding topics, where superficially correct responses may obscure deeper conceptual deficiencies (Freire et al., 2019). Accordingly, the expert ratings obtained provide substantive support for the claim that CHEM-LENS items accurately operationalize intended chemistry competencies rather than peripheral or construct-irrelevant content.

Analysis of item functioning further corresponds with diagnostic assessment literature reporting moderate variability in item discrimination during the early phases of instrument validation (Walpuski & Celik, 2023). Such variability is not necessarily indicative of instrument weakness but may instead reflect heterogeneous patterns of student understanding across chemistry domains. Consistent with recommendations for exploratory diagnostic instruments, the retention of conceptually essential items despite marginal statistical indicators prioritizes content representativeness and instructional utility over premature statistical optimization (DeVellis, 2017; Putica, 2022).

Moreover, the observed internal consistency reliability supports the interpretation that CHEM-LENS functions cohesively as a diagnostic instrument despite encompassing multiple chemistry topics. Comparable reliability coefficients have been reported in recent chemistry education studies developing tools for formative or diagnostic purposes, particularly when the primary objective is the identification of learning needs rather than normative student ranking (Amalia & Habiddin, 2024; Ridlo et al., 2024; Mi & Ye, 2023). Collectively, these findings indicate that CHEM-LENS satisfies accepted standards for preliminary diagnostic use and establishes a robust foundation for subsequent psychometric refinement and extended validation efforts.

Chemistry Learning Needs Across Curriculum Topics

Following the preliminary validation of CHEM-LENS, the instrument was administered to examine students' chemistry learning needs across major curriculum-aligned content domains. Item-level difficulty indices derived from students' response patterns were employed as diagnostic indicators of relative learning need within and across topics. These indices provided an empirical basis for identifying domains characterized by higher levels of conceptual difficulty and instructional priority. A summary of the resulting learning need profiles across curriculum topics is presented in Table 2.

Table 2. Chemistry Learning Needs Assessment Results Based on CHEM-LENS

Rank	Chemistry Topic	Difficulty (%)	Learning Need Descriptor
1	Thermochemistry and Chemical Kinetics	85 %	High
2	Chemical Reactions	75 %	High
3	Chemical Bonding	74.%	High
4	Atomic Structure and the Periodic Table	66.25 %	High
5	Gases and Gas Laws	63.75 %	Moderate
6	Nuclear Chemistry	57.50 %	Moderate

7	Organic Chemistry and Biochemistry	55 %	Moderate
8	Solutions, Acids, and Bases	53.75%	Moderate
9	Matter and Its Properties	48.75 %	Low
10	Chemistry in Everyday Life and the Environment	40 %	Low

The differentiated pattern of chemistry learning needs presented in Table 2 is consistent with well-documented trends in chemistry education research, particularly the persistent difficulties students encounter in conceptually demanding topics that require the coordinated use of macroscopic observations, symbolic representations, and submicroscopic explanations (Farillon, 2022; Freire et al., 2019). Such representational integration is widely recognized as a core challenge in chemistry learning, and deficiencies in this area often manifest as fragmented understanding and limited transfer across contexts.

Consistent with prior studies, energy-related concepts and chemical reaction processes emerged as areas of heightened learning need. Research by Nazir and Kanwal (2025) and Khoiriyah et al. (2025) similarly identifies these topics as among the least mastered at the secondary level. These enduring difficulties have been attributed not only to the mathematical demands inherent in energy calculations and reaction stoichiometry but also to students' limited ability to connect symbolic equations with the molecular-level processes they are intended to represent. The present findings reinforce these conclusions by demonstrating that such conceptual challenges persist at the Senior High School level, even after extended curricular exposure (Tupas & Matsuura, 2019).

Difficulties related to chemical bonding and atomic structure identified in this study likewise align with prior research linking these domains to representational overload and the development of fragmented or unstable mental models (Amalia & Habiddin, 2024; Suparman et al., 2024). When chemistry instruction prioritizes algorithmic problem solving without sufficient conceptual scaffolding, students may demonstrate procedural proficiency while failing to construct coherent explanatory frameworks. This pattern has been documented among Filipino learners and underscores the need for instructional approaches that explicitly support representational integration and conceptual sense-making (Barcelo, 2024).

Domains categorized as exhibiting moderate learning needs—including gases and gas laws, nuclear chemistry, and organic chemistry and biochemistry—are consistent with findings reported by Horvat and Rodić (2023), who observed that students often display partial or context-dependent understanding in these areas. Such topics typically involve substantial mathematical abstraction, as in the case of gas laws, or theoretical models that are conceptually distant from everyday experience, as seen in nuclear processes. Existing research suggests that learning difficulties in these domains tend to be topic-specific rather than systemic, indicating that targeted instructional interventions may be more effective than broad curricular restructuring (Sayre et al., 2025).

In contrast, the lower levels of learning need observed in domains such as matter and its properties and chemistry in everyday life are consistent with studies emphasizing the role of contextualization and familiarity in reducing perceived difficulty (Djaen & Rahayu, 2021; Eilks et al., 2020; Tiara & Sulistina, 2021). Context-based instruction and the integration of real-life applications have been shown to support student engagement and conceptual accessibility, particularly for foundational chemistry concepts. Nevertheless, as cautioned by Freire et al. (2019), lower observed difficulty in familiar contexts does not necessarily indicate robust conceptual understanding, as misconceptions may remain latent and only become apparent when students encounter more abstract or unfamiliar applications.

Taken collectively, these findings support the utility of CHEM-LENS as a diagnostic instrument capable of revealing nuanced patterns of chemistry learning needs that are consistent with established research. By employing a scenario-based, multiple-choice diagnostic format, CHEM-LENS captures students' capacity to apply conceptual understanding within context, thereby addressing limitations of traditional summative assessments that often obscure topic-specific learning gaps (Khoiriyah et al., 2025; Rokhim et al., 2024). This

approach aligns with needs assessment theory, which emphasizes the generation of actionable diagnostic evidence to inform instructional planning and curriculum refinement (McKillip, 1987; Witkin & Altschuld, 1995).

From a measurement perspective, the integration of content validation, item analysis, and reliability evidence reflects contemporary best practices in educational instrument development (DeVellis, 2017). Although the present study is limited to preliminary validation, the findings establish a credible empirical foundation for subsequent research involving construct validation, broader sampling, and the instructional application of CHEM-LENS.

CONCLUSION

This study documented the development and preliminary validation of CHEM-LENS, a curriculum-aligned diagnostic instrument designed to identify chemistry learning needs among Senior High School students. Through a staged development process, initial evidence was established for the instrument's content relevance, item functioning, and internal consistency reliability, supporting its suitability for exploratory diagnostic use.

Application of CHEM-LENS revealed a differentiated profile of chemistry learning needs, with higher levels of difficulty concentrated in conceptually demanding and abstract domains such as thermochemistry, chemical reactions, chemical bonding, and atomic structure. These findings are consistent with existing chemistry education research and underscore the persistent challenges students face in integrating conceptual, symbolic, and representational aspects of chemistry learning.

By consolidating validation evidence with learning need outcomes, this study highlights the value of diagnostic assessment as a complement to traditional summative evaluation in chemistry education. CHEM-LENS provides educators and curriculum planners with empirically grounded information that can support targeted instructional planning and evidence-informed decision-making.

Although the findings are bounded by the study context and sample size, they establish a sound foundation for further research and instrument refinement. With comprehensive psychometric validation and broader field application, CHEM-LENS has the potential to contribute meaningfully to data-informed instructional practices and ongoing efforts to enhance student learning in chemistry.

RECOMMENDATION

Based on the findings of this study, the following recommendations are proposed to strengthen the measurement quality and applicability of CHEM-LENS:

1. **Conduct Comprehensive Psychometric Validation.** Future studies may extend validation efforts beyond preliminary evidence by examining construct validity, dimensional structure, and item characteristics using advanced statistical techniques such as exploratory and confirmatory factor analysis and item response theory. Comprehensive validation would provide stronger empirical support for the instrument's use in diagnostic, instructional, and research contexts.

2. **Expand Sampling Across Diverse Educational Contexts.** Subsequent research may administer CHEM-LENS to larger and more diverse student populations across multiple schools and instructional settings. Broadening the sample base would enhance the generalizability of findings, improve the stability of psychometric estimates, and enable meaningful comparisons across student subgroups and curricular contexts.

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