Beyond Symbols and Trends: Conceptual Understanding and Motivation in Periodic Table Learning among Grade 9 Students

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ABSTRACT

Mastery of the periodic table of elements constitutes a foundational component of chemistry education, fostering both scientific literacy and higher-order cognitive skills. Nevertheless, Grade 9 learners frequently encounter challenges in internalizing its abstract concepts. This study investigated the relationship between conceptual understanding of the periodic table and motivational dispositions among Grade 9 students at Acelo Badelles Sr. Memorial High School in Iligan City, Philippines. Utilizing a descriptive-correlational design, data were collected through a 28-item Conceptual Understanding Questionnaire and a Motivation Survey, with a total sample of 140 participants. Results revealed substantial learning deficiencies, as none of the respondents achieved the established passing threshold of 75%. Topics necessitating advanced cognitive processing, including periodic trends and electron configurations, were identified as particularly challenging. Spearman's rank correlation analysis revealed a weak but statistically significant positive association ($\rho = 0.2685$), suggesting that motivation contributes modestly—but not exclusively—to conceptual understanding. Although students acknowledged the significance of the periodic table for scientific comprehension, many reported difficulties sustaining engagement and expressed a preference for interactive, hands-on instructional approaches. These findings underscore the imperative for implementing innovative pedagogical strategies, such as gamification, experiential learning, contextually relevant interventions, and the like to concurrently enhance comprehension and motivation. The research instruments exhibited acceptable reliability, with Cronbach's alpha values of 0.80 for the achievement test and 0.88 for the motivation survey.

Keywords: Conceptual understanding, motivation, periodic table, science education

INTRODUCTION

Comprehension of the periodic table of elements constitutes a foundational component of chemistry education, serving as an essential framework for organizing chemical elements and predicting their behaviors. Mastery of this domain is critical for understanding core chemical principles and for facilitating the development of higher-order cognitive skills. Nevertheless, many students, particularly those at the Grade 9 level, encounter persistent difficulties in both the conceptual and practical applications of the periodic table. These challenges manifest in students' struggles with competencies such as identifying element symbols, atomic numbers, atomic masses, and discerning periodic trends, which are frequently categorized as least-learned competencies.

Empirical studies have consistently highlighted these instructional challenges. Adesoji and Olatunbosun (2008) identified that students' difficulties with abstract scientific concepts, including the periodic table, are often exacerbated by pedagogical practices that prioritize rote memorization over active engagement and interactive learning. Similarly, Taber (2002) observed that students often experience cognitive overload when navigating symbolic representations of elements and the complex relationships between macroscopic chemical properties and submicroscopic structures, such as electron configurations and chemical bonding. These difficulties inhibit the ability of learners to apply their knowledge in authentic contexts or to develop a deeper understanding of advanced chemical concepts.

Motivation has been demonstrated to play a pivotal role in mitigating these learning challenges. According to Ryan and Deci (2000), the interplay of intrinsic motivation, derived from personal interest and satisfaction, and extrinsic motivation, such as recognition or rewards, fosters a conducive learning environment. Conversely, insufficient motivation exacerbates students' struggles with abstract topics, reducing engagement and, consequently, academic achievement. In the context of chemistry, the lack of motivation impedes the development of meaningful connections between theoretical knowledge and practical application, undermining conceptual understanding and retention.

Conceptual understanding is central to effective science education. Bransford, Brown, and Cocking (2000) emphasized that meaningful learning arises when students can link theoretical constructs to experiential and practical contexts. Novak (1998) similarly posited that learning is optimized when students integrate new information into preexisting cognitive frameworks. In chemistry education, Taber (2015) underscored that comprehension of the periodic table necessitates more than memorization; it requires students to engage with abstract concepts to discern patterns and relationships among elements, their properties, and their applications in everyday contexts.

Addressing these persistent challenges demands the implementation of innovative, student-centered instructional approaches. Interactive strategies, including gamified learning tools, have been shown to enhance both conceptual understanding and learner motivation. McGonigal (2011) highlighted that immersive, game-based learning environments can foster deeper engagement, facilitate active knowledge construction, and support mastery of complex scientific concepts. By leveraging such pedagogical strategies, educators can assist students in overcoming difficulties with the least-learned competencies of the periodic table, thereby establishing a robust foundation for advanced studies in chemistry and promoting sustained scientific literacy.

METHODOLOGY

The primary objective of this study was to develop a validated and reliable multiple- choice assessment instrument designed to measure Grade 9 students' conceptual understanding of the periodic table of elements. The development process adhered to rigorous standards for educational measurement, incorporating expert validation, pilot testing, and reliability analysis to ensure both content accuracy and psychometric robustness.

Participants. Purposive sampling was employed to select participants for this study, focusing specifically on Grade 9 learners enrolled in public high schools. The initial pilot testing of the assessment instrument was conducted at Acelo Badelles Sr. Memorial High School in Iligan City, Philippines, with a total of 140 students participating. Following an initial analysis of item performance, including difficulty and discrimination indices, a refined version of the instrument was administered to a smaller subset of 40 students to confirm reliability and validity. All assessments were conducted using traditional pen-and-paper administration to maintain standardization across participants.

Development of the Assessment Instrument. The assessment instrument was constructed as a multiple-choice questionnaire to evaluate students' conceptual understanding of the periodic table. Version 1 of the instrument comprised 40 items aligned with the Most Essential Learning Competencies (MELCs) stipulated in the Department of Education's K–12 Science Curriculum for Grade 9. Items addressed key concepts, including element symbols, atomic numbers, atomic mass, periodic trends, and practical applications of the periodic table.

To ensure content validity and appropriateness for the target population, Version 1 underwent expert review by three validators with specialized expertise in chemistry education and science pedagogy. The validators assessed each item for clarity, cognitive demand, alignment with learning objectives, language appropriateness, and practical applicability. Feedback from this expert evaluation informed revisions, resulting in Version 2 of the instrument.

Version 2 was pilot-tested with 140 Grade 9 students under standardized conditions. Item analysis was conducted using discrimination and difficulty indices to determine each item's ability to differentiate between high- and low-performing students. Items failing to meet the established psychometric criteria were eliminated, resulting in a final Version 3 consisting of 28 items. The final instrument retained only the most reliable and valid items, targeting a range of cognitive demand levels, from basic recall to higher-order thinking, and incorporating real-world scenarios to enhance relevance and engagement.

Validation and Reliability Testing. The iterative development process included multiple stages of validation and reliability assessment. Expert validation ensured alignment with intended learning outcomes, while pilot testing and item analysis confirmed the instrument's capacity to accurately measure conceptual understanding. Reliability was further supported through internal consistency analysis, ensuring that the final instrument provided a stable and robust measure of students' knowledge of the periodic table.

Application of the Instrument. The validated instrument was subsequently deployed to identify least-mastered competencies among Grade 9 learners, focusing on areas such as element symbols, atomic numbers, atomic mass, and periodic trends. Data collected through this instrument offered actionable insights into students' conceptual understanding, informing targeted instructional interventions designed to address gaps in learning and promote higher-order cognitive engagement in chemistry.

By systematically integrating expert validation, psychometric evaluation, and iterative refinement, this methodology provides a rigorous framework for the development and application of assessment tools in science education, contributing to evidence-based evaluation practices and enhanced instructional design. As this study employed a descriptive-correlational design, causal relationships between motivation and conceptual understanding cannot be inferred. The findings are therefore interpreted in terms of association rather than cause-and-effect.

Data Analysis. Data analysis in this study employed a combination of descriptive, inferential, and psychometric methods to ensure both the reliability and validity of the assessment instrument and to examine the relationships among conceptual understanding, motivation, and academic achievement. Descriptive statistics, including mean and standard deviation, were calculated to summarize participants' levels of conceptual understanding and perceived motivation.

The internal consistency of the conceptual understanding test and the motivation scale was evaluated using Cronbach's alpha, with values of 0.70 or higher deemed acceptable for establishing reliability (Gliem & Gliem, 2003). Item analysis was conducted to assess the quality of individual test items. The discrimination index was used to identify items capable of effectively differentiating between high- and low-performing students. Items that did not meet established criteria for clarity, relevance, or psychometric quality were either revised or removed. This process resulted in a final 28-item instrument that retained only the most reliable and valid items, ensuring alignment with the study's objectives and the cognitive demands of the assessed competencies.

To explore the relationships between conceptual understanding and motivation, Pearson's correlation coefficient was computed. This analysis provided insights into the strength and direction of associations between these variables. To maintain participant confidentiality and facilitate systematic data management, unique codes were assigned to all participants. These codes were consistently applied across all instruments and assessment iterations, supporting accurate data organization, analysis, and interpretation of variable interrelationships.

Through this rigorous approach to data analysis, the study ensured both the psychometric integrity of the assessment instrument and the robustness of conclusions drawn regarding the interplay between students' conceptual understanding, motivation, and academic performance.

RESULT AND DISCUSSION

Item Analysis and Instrument Validation. The assessment questionnaire underwent a systematic item analysis and validation process to ensure its effectiveness in measuring Grade 9 learners' conceptual understanding of the periodic table. The evaluation focused on three primary dimensions: alignment with the Most Essential Learning Competencies (MELCs), item discrimination, and internal reliability. Version 1 of the questionnaire consisted of 40 multiple-choice items. Three validators, all experts in chemistry education, assessed each item for clarity, relevance, and alignment with the MELCs. Feedback from this expert review informed revisions, yielding Version 2 with enhanced construct and content validity.

Pilot testing of Version 2 involved 140 Grade 9 learners at Acelo Badelles Sr. Memorial High School. Item analysis was conducted using the discrimination index to evaluate each item's ability to differentiate between high- and low-performing students. Items demonstrating low discrimination or ambiguous phrasing were excluded, resulting in the finalized Version 3, which comprised 28 validated items. This iterative process ensured the development of a psychometrically robust assessment instrument.

Version 3 of the Conceptual Understanding Questionnaire was aligned with the Third Grading MELCs in Science and consisted of 28 multiple-choice items, each with four answer choices. The distribution of cognitive demands across the instrument followed Bloom's Taxonomy: 25% understanding, 25% analyzing, 17.86% applying, 14.29% evaluating, and 17.86% creating. This distribution balanced the assessment of foundational knowledge with higher-order thinking skills, promoting critical thinking and problem-solving in the context of the periodic table.

Item difficulty analysis conducted on Version 2 categorized items as easy (5%), moderately challenging (70%), and difficult (25%). Only the 28 moderately challenging items were retained in Version 3, ensuring an optimal balance between accessibility and cognitive demand. Pilot testing of Version 3 demonstrated its reliability and validity, confirming its utility as a tool for evaluating learners' conceptual understanding of the periodic table while capturing performance across multiple cognitive domains.

Performance Analysis of the Trial Group. The analysis of Grade 9 learners' performance on Version 3 of the Conceptual Understanding Questionnaire revealed persistent challenges with abstract chemical concepts. Descriptive statistics indicated a mean score of 12.15 ($SD = 4.03$) out of a maximum possible score of 28, with none of the participants achieving the passing threshold of 75% accuracy (Table 1). This underscores substantial gaps in both foundational and higher-order competencies related to the periodic table.

Higher-order cognitive skills, particularly evaluating and creating, were the most difficult for learners, consistent with previous literature documenting challenges in applying abstract concepts to problem-solving and real-world contexts (Taber, 2002; Adesoji & Olatunbosun, 2008). Topics including periodic trends, electron configurations, and the relationship of element properties to practical applications yielded the highest proportion of incorrect responses, indicating areas requiring targeted instructional interventions.

Correlation Between Conceptual Understanding and Motivation. Pearson correlation analysis was conducted to examine the relationship between learners' conceptual understanding and self-reported motivation. Results indicated a weak but positive correlation, $r = .27$, $p < .01$, suggesting that higher levels of motivation were modestly associated with better performance on the periodic table assessment (Figure 1). Although the association is not strong, these findings align with prior research emphasizing the importance of motivation in facilitating engagement and learning in complex scientific domains (Ryan & Deci, 2000; Nzomo, Rugano, & Njoroge, 2023). Scatterplot depicting the relationship between conceptual understanding and motivation among Grade 9 learners ($N = 140$).

These findings highlight the dual need for instructional strategies that simultaneously enhance both motivation and conceptual understanding. Incorporating student-centered, interactive learning approaches, such as gamified activities and problem-based learning, may provide the necessary scaffolding to improve mastery of abstract chemical concepts while sustaining learner engagement. Although statistically significant, the weak magnitude of the correlation indicates that motivation alone is insufficient to account for learners' conceptual understanding of the periodic table. This suggests the influence of additional factors such as prior knowledge, instructional strategies, and the abstract nature of chemical concepts. From an educational perspective, this finding highlights the need for instructional approaches that simultaneously address cognitive scaffolding and motivational support rather than relying on motivational enhancement alone.

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Table 1. Mastery Level of Grade 9 learners on Learning Competencies

Skills Tested	**Frequency of error**	%	**No. of correct respon ses**	%	**Mastery Level**
Use properties of matter to identify substances and to separate them.	16	40	24	60	Least Mastered
Use the periodic table to predict the chemical behavior of an element	21	51.76	19	49.24	Not Mastered
Mean Percentage Score	18.5	**45.38**	21.5	**54.62**	Least Mastered

Legend: Not mastered (50 % below}, Least mastered (51-74%), Nearly Mastered (75- 79%}, Mastered (80-100%)

The analysis of Grade 9 learners' performance revealed substantial deficiencies in competencies associated with the periodic table of elements and the properties of matter. As summarized in Table 5, the overall mean percentage score was 54.62%, indicating that the majority of participants had not achieved mastery in these foundational domains. The highest mean performance, observed in the competency related to utilizing the properties of matter to identify and separate substances, was 60%, yet this was still classified as "least mastered."

Notably, students exhibited pronounced difficulties in applying the periodic table to predict chemical behaviors, with only 49.24% of responses correct. Additional competencies demonstrating minimal mastery included identifying substances based on their intrinsic properties (40% correct) and predicting chemical behavior through the periodic table (51.76% correct). These findings suggest that learners experience challenges not only in conceptualizing the properties of matter but also in translating this understanding into predictive applications using the periodic table.

The overall performance profile underscores the need for pedagogical interventions that target both conceptual comprehension and applied reasoning in chemistry. The distribution of scores further indicates that the assessment primarily comprised cognitively demanding items, which may have contributed to the lower mean achievement. Consequently, these results highlight an imperative for instructional strategies that scaffold complex concepts and enhance students' capacity to engage critically with abstract chemical principles.

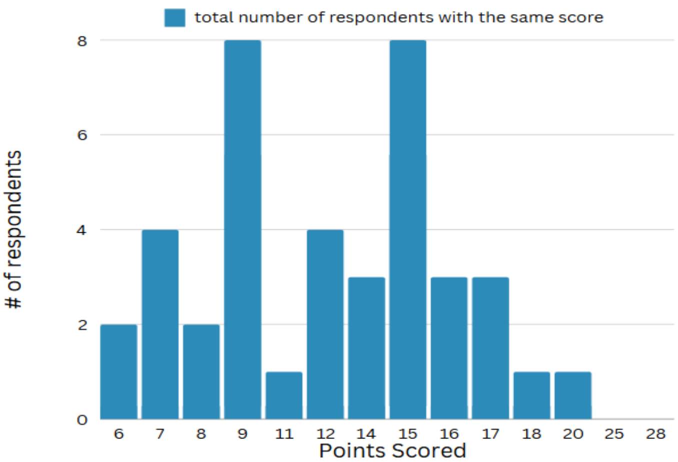

Figure 1. Score Distribution in Percentage

Figure 1 illustrates the distribution of scores obtained by Grade 9 learners on the Conceptual Understanding Questionnaire. Respondents' scores ranged from 6 to 20, with the most frequent scores occurring at 9 and 15, each achieved by eight students. The mean score was approximately 12, indicating that the central tendency lies in the lower-middle range of the possible score spectrum.

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The figure demonstrates a moderate dispersion of scores, with concentrations clustered around the middle of the distribution. Despite this variability, the majority of students achieved scores below the 75% mastery threshold, highlighting persistent gaps in conceptual understanding of the periodic table. This pattern suggests that learners encounter significant challenges in mastering core concepts, underscoring the need for targeted instructional strategies to enhance comprehension and application of periodic table principles.

Relationship Between Motivation and Conceptual Understanding

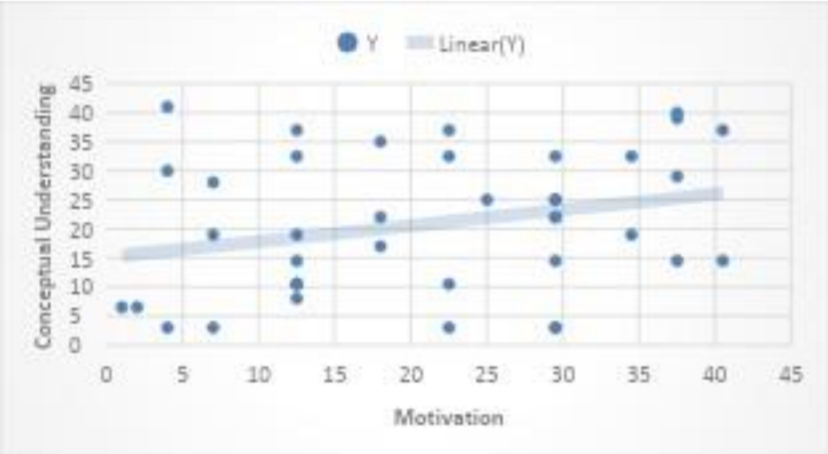

Figure 2. Scatterplot of Conceptual Understanding by Motivation

Spearman's rank-order correlation analysis revealed a weak but positive association between students' motivation and their performance on the Conceptual Understanding Questionnaire (ρ = 0.2685, $p < .01$). This finding indicates that higher levels of motivation are modestly associated with better conceptual understanding of the periodic table; however, the strength of this relationship is limited. Thus, while motivation appears to play a contributory role in learning outcomes, it is not the sole determinant of conceptual mastery.

Scatterplot analysis further illustrates this relationship. The data points exhibit considerable dispersion across both axes, reflecting variability in students' motivation and conceptual understanding. Clusters of points along specific vertical ranges suggest the influence of additional factors, such as prior knowledge, instructional exposure, or cognitive strategies, which may moderate or confound the observed relationship. The absence of a clear, consistent trend reinforces the interpretation that motivation alone is insufficient to predict conceptual understanding reliably.

Collectively, these results underscore the multifactorial nature of learning in chemistry. While motivation contributes to performance, effective instructional design must also address other cognitive and contextual variables to optimize conceptual comprehension. These findings are consistent with prior research emphasizing the complex interplay between affective and cognitive factors in science education (Ryan & Deci, 2000; Taber, 2015).

Limitations Of the Study

This study is subject to several limitations. First, the descriptive-correlational design limits causal interpretation of the relationship between motivation and conceptual understanding. Second, the sample was drawn from a single public high school, which may restrict the generalizability of the findings. Finally, while the assessment instrument demonstrated acceptable reliability and validity, learners' performance may have been influenced by instructional alignment and prior exposure to periodic table concepts.

CONCLUSION AND RECOMMENDATION

The researcher-developed achievement test demonstrated acceptable internal consistency with a Cronbach's alpha coefficient of 0.80. Likewise, the 20-item motivation survey yielded a Cronbach's alpha of 0.88, indicating good reliability. These values suggest that the instruments were suitable for measuring learners' academic achievement and motivation. The present study underscores the critical need for targeted instructional interventions to mitigate gaps in both conceptual understanding and student motivation in the context of the periodic table of elements. Although the observed correlation between motivation and conceptual performance was weak ($\rho = 0.2685$), motivation remains a salient factor, particularly when reinforced through engaging and interactive pedagogical strategies. The findings highlight the inherent challenges associated with the abstract nature of the periodic table, which impede students' capacity to translate theoretical knowledge into meaningful real-world applications. Traditional didactic approaches appear insufficient to address these limitations, necessitating the adoption of innovative teaching methodologies. Approaches such as gamification, hands-on laboratory activities, and contextualized learning experiences have demonstrated potential to enhance conceptual comprehension and sustain learner engagement. Specifically, the development of educational tools, such as the board game Elemental Expedition, may provide an immersive, game-based platform to reinforce periodic table concepts while simultaneously increasing motivation and knowledge retention. Additionally, the study emphasizes the importance of ongoing professional development for educators in contemporary instructional strategies, including inquiry-based learning and gamified pedagogy, to equip teachers with the skills necessary to address diverse learning needs and optimize student outcomes in chemistry education. Future studies may adopt experimental or quasi-experimental designs to evaluate the causal effects of specific instructional interventions, such as gamified learning tools or inquiry-based approaches, on both motivation and conceptual understanding. Expanding the sample to multiple schools or regions would enhance generalizability. Moreover, aligning innovative strategies with the K–12 curriculum and supporting teachers through targeted professional development programs may strengthen classroom implementation and learning outcomes.

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