Assessing Conceptual Understanding and Misconceptions of the Periodic Table among Grade 10 Learners: A Diagnostic Approach

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ABSTRACT

This study aimed to investigate the learning gaps and misconceptions of Grade 10 students regarding the Periodic Table of Elements through a systematically developed and validated diagnostic assessment instrument. Employing a descriptive research design, an initial 50-item test was content-validated by three experts and pilottested with 150 students. Item analysis and reliability assessment using Cronbach's alpha resulted in a finalized 36-item diagnostic tool, which was subsequently administered to 100 Grade 10 students from selected public secondary schools in the hinterland areas of Iligan City. Data were analyzed using mean scores and percentage distributions to identify learning gaps and patterns of incorrect responses. Findings revealed persistent misconceptions in foundational concepts, including atomic structure, differentiation between atomic number and mass number, historical development of the Periodic Table, and periodic trends such as atomic radius, ionization energy, and electronegativity. Many learners demonstrated difficulty explaining these trends in terms of underlying principles, including effective nuclear charge and electron shielding. These results underscore the need for targeted instructional interventions that address misconceptions and foster deeper conceptual understanding of the Periodic Table. The validated diagnostic tool provides a robust foundation for designing remedial strategies and enhancing chemistry instruction at the secondary school level.

Keywords: Chemistry Education, Diagnostic Assessment, Learning Gaps, Misconceptions, Periodic Table of Elements

INTRODUCTION

The Periodic Table of Elements constitutes a foundational framework in chemistry education, providing a systematic tool for understanding atomic structure, periodic trends, chemical properties, and elemental behavior. Mastery of the Periodic Table enables learners to predict chemical reactivity, interpret bonding patterns, and integrate concepts across diverse chemistry topics. Consequently, a robust conceptual understanding of periodic relationships is essential for scientific literacy and progression in STEM disciplines. Despite its centrality, numerous studies have documented persistent learner difficulties in comprehending the

Periodic Table. Research indicates that students often rely on rote memorization of element symbols and positions without developing a principled understanding of the underlying atomic principles (National Research Council, 2012). Misconceptions related to atomic size, electronegativity, ionization energy, and periodicity remain prevalent even after formal instruction (Cooper et al., 2017; Taber, 2013).

Evidence from both international and local assessments further underscores these challenges. The Trends in International Mathematics and Science Study (TIMSS, 2019) reported that Filipino learners performed below the international average on items involving classification and properties of matter—concepts closely linked to the Periodic Table. Locally, empirical studies have shown that Grade 10 learners struggle to articulate periodic trends and frequently fail to associate an element's position with its atomic properties, resulting in fragmented conceptual understanding (Necor, 2018; DepEd, 2020). One contributing factor to these difficulties is the reliance on conventional classroom assessments, which predominantly emphasize factual recall rather than probing conceptual understanding and reasoning processes. As a result, misconceptions and learning gaps often remain undetected. In chemistry education, diagnostic assessment has been recognized as a powerful tool for identifying learners' alternative conceptions and least mastered competencies (Treagust, 1988; Mulford & Robinson, 2002).

Grounded in constructivist learning theory, conceptual change theory, and principles of assessment for learning,

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diagnostic assessments provide critical insights into how learners construct, apply, and sometimes misunderstand scientific concepts. Identifying misconceptions is a crucial step in designing instructional interventions that facilitate conceptual change and promote deeper understanding. Given the persistent difficulties associated with learning the Periodic Table and the scarcity of validated diagnostic tools at the junior high school level, the present study sought to develop and validate a diagnostic assessment instrument aimed at identifying Grade 10 learners' learning gaps and misconceptions concerning the Periodic Table of Elements.

METHODS

Research Design

This study employed a descriptive research design to identify learning gaps and misconceptions of Grade 10 learners regarding the Periodic Table of Elements using a developed and validated diagnostic assessment instrument. The design focused on describing learners' mastery levels across selected Periodic Table concepts through descriptive statistical analysis. In addition, the study evaluated the psychometric properties of the diagnostic instrument through pilot testing, item analysis, and reliability assessment to ensure its suitability for diagnostic purposes.

Settings and Participants

The study was conducted in selected public secondary schools in Iligan City and surrounding hinterland areas in the Philippines. Pilot testing was implemented at Iligan City East National High School, whereas the standardized diagnostic test was administered at Kabacsanan National High School and Hindang National High School. A total of 150 Grade 10 learners participated in the pilot phase, and 100 Grade 10 learners participated in the final administration of the standardized diagnostic instrument. Participants were selected based on enrollment in Grade 10 and prior exposure to the Periodic Table of Elements within the junior high school chemistry curriculum. Participation was voluntary, and informed consent was obtained from all learners prior to data collection.

Instrument

The research instrument was a researcher-developed multiple-choice diagnostic test designed to assess conceptual understanding of the Periodic Table of Elements. The initial version comprised 50 items aligned with the Grade 10 Most Essential Learning Competencies (MELCs) under the K to 12 curriculum. The instrument addressed key concepts, including atomic structure, element classification, periodic trends, historical development of the periodic table, and atomic properties. Content validation was conducted by three doctorallevel experts in Chemistry and Science Education, whose feedback informed revisions to enhance clarity, relevance, and alignment with curricular objectives. Readability analyses were performed using the SMOG and Flesch–Kincaid Grade Level tests to ensure suitability for Grade 10 learners. Following validation, the instrument underwent pilot testing, and item analysis was conducted to determine item difficulty and discrimination indices. Items were retained, revised, or rejected based on cross-tabulation criteria, resulting in a final 36-item standardized diagnostic test used in the main data collection phase.

Table 1. Interpretations of Learner Performance in the Diagnostic Test

Percentage	Remarks
90-100	Passed
85-89	Passed
80-84	Passed
75-79	Passed
Below 75	Failed

Data Analysis

Descriptive statistical methods were employed to analyze learners' performance and evaluate the psychometric quality of the diagnostic instrument. Mean scores and percentage distributions were computed to determine

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overall mastery levels and to identify least mastered concepts, as well as recurring misconceptions related to the Periodic Table of Elements. Item quality was assessed using the Index of Difficulty (p) and the Index of Discrimination (D), following the criteria outlined by Ebel and Frisbie (1991). A cross-tabulation matrix guided decisions regarding item retention, revision, or elimination. The internal consistency reliability of the instrument was established using Cronbach's alpha based on pilot testing data. Learners' performance was interpreted in accordance with the DepEd K to 12 Grading System (DepEd Order No. 8, s. 2015), providing a qualitative framework for understanding levels of mastery across the assessed competencies. **Table 2.** Discrimination Index and Verbal interpretation

Discrimination Index	Verbal Interpretation
0.40 and above	Excellent item
0.30-0.39	Reasonably good
0.20-0.29	Marginal item
Below 0.19	Poor item or non-discriminating

Ebel, R. L., & Frisbie, D. A. (1991)

Table 3. Difficulty Index and Verbal interpretation

Difficulty Index	Verbal Interpretation
0.00 – 0.20	Very Difficult
0.21 – 0.40	Difficult
0.41 – 0.60	Average
0.61 – 0.80	Easy
0.81 – 1.00	Very Easy

Ebel, R. L., & Frisbie, D. A. (1991)

Table 4. Cross-tabulation Table of the Discrimination Index and Difficulty Index

Difficulty Index	Discrimination Index			
	0.40 and above (Excellent item)	0.30-0.39 (Reasonably Good)	0.20-0.29 (Marginal item)	Below 0.19 (Poor item or nondiscriminating)
0.0 – 0.20 (Very difficult)	Retain	Revise	Revise	Reject
0.21 – 0.40 (Difficult)	Retain	Retain	Revise	Reject
0.41 – 0.60 (Average)	Retain	Retain	Revise	Reject
0.61 – 0.80 (Easy)	Retain	Retain	Revise	Reject
0.80 – 1.00 (Very Easy)	Retain	Revise	Revise	Reject

Ethical Considerations

Ethical standards were rigorously observed throughout the study. Informed consent was obtained from all participants and their parents or guardians prior to data collection. Participation was entirely voluntary, and learners were informed of their right to withdraw from the study at any point without penalty. Confidentiality

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was maintained through the use of coded identifiers, and all data were strictly used for research purposes. These measures ensured adherence to established ethical guidelines in educational research.

RESULTS AND DISCUSSION

Performance of Learners on the Diagnostic Test

This section presents the results of the pilot administration of the diagnostic test, which was conducted to evaluate the quality, reliability, and suitability of the instrument prior to standardization. The initial version of the test consisted of 50 multiple-choice items designed to assess learners' conceptual understanding of key topics related to the Periodic Table of Elements. Results from the pilot testing served as the basis for item analysis and subsequent refinement of the instrument.

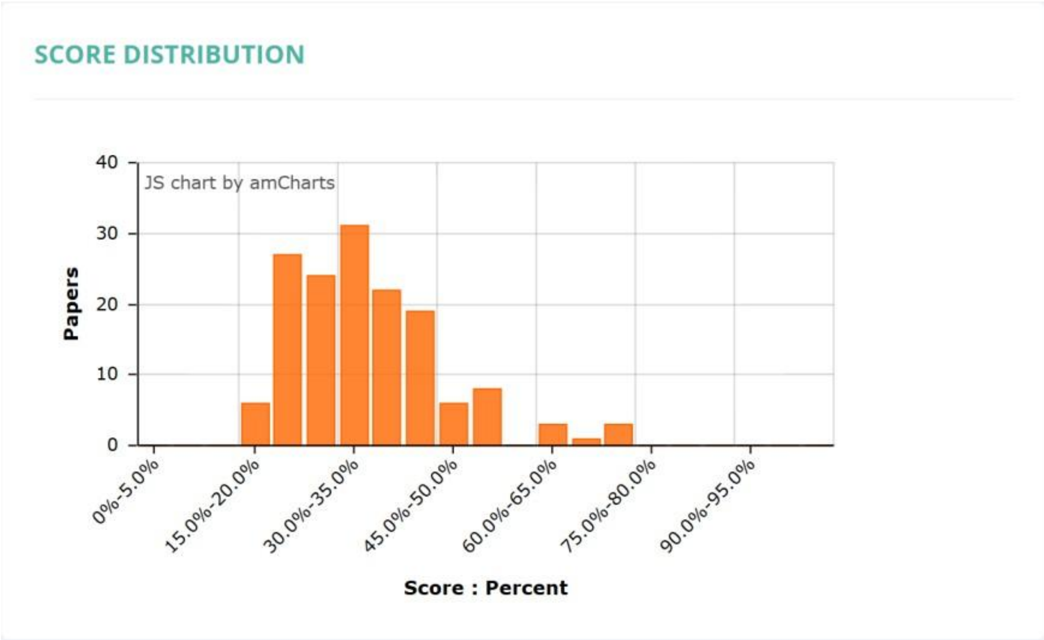

Figure 1. Total Score Distribution

Figure 1 illustrates the distribution of total scores obtained during the pilot administration of the diagnostic test. The wide range of scores indicates substantial variability in learners' conceptual understanding, demonstrating that the instrument is sufficiently sensitive for diagnostic purposes and capable of distinguishing between varying levels of learner performance.

Item analysis was conducted using the Index of Difficulty (p) and the Index of Discrimination (D) to evaluate the statistical performance of each test item. Based on these indices, items were categorized for retention, revision, or rejection. Items exhibiting acceptable levels of difficulty and discrimination were retained, whereas items with marginal values were revised to enhance clarity and ensure alignment with the intended competencies. Items that did not meet the established statistical criteria were eliminated from the instrument. This rigorous process ensured that the final standardized diagnostic test comprised only psychometrically sound items. A summary of the item analysis outcomes is presented in Table 5, while the overall classification is summarized in Table 6.

Table 5. Difficulty and Discrimination Indices of the Diagnostic Test Items

Item No.	Difficulty Index	Interpretation	Discrimination Index	Interpretation	Decision
1	0.1125	VERY DIFFICULT	0.225	MARGINAL ITEM	REVISE
2	0.15	VERY DIFFICULT	0.2	MARGINAL ITEM	REVISE

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3	0.6125	EASY	0.375	REASONABLY GOOD	RETAIN
4	0.2875	DIFFICULT	0.075	NON-DISCRIMINATING	REJECT
5	0.4125	AVERAGE	0.225	MARGINAL ITEM	REVISE
6	0.2875	DIFFICULT	0.225	MARGINAL ITEM	REVISE
7	0.2375	DIFFICULT	0.125	POOR ITEM	REJECT
8	0.2875	DIFFICULT	0.125	POOR ITEM	REJECT
9	0.25	DIFFICULT	0.25	MARGINAL ITEM	REVISE
10	0.3625	DIFFICULT	0.175	POOR ITEM	REJECT
11	0.3875	DIFFICULT	0.225	MARGINAL ITEM	REVISE
12	0.375	DIFFICULT	0.35	REASONABLY GOOD	RETAIN
13	0.425	AVERAGE	0.25	MARGINAL ITEM	REVISE
14	0.5875	AVERAGE	0.325	REASONABLY GOOD	RETAIN
15	0.4375	AVERAGE	0.125	POOR ITEM	REJECT
16	0.4125	AVERAGE	0.275	MARGINAL ITEM	REVISE
17	0.1875	VERY DIFFICULT	0.125	POOR ITEM	REJECT
18	0.45	AVERAGE	0.4	EXCELLENT ITEM	RETAIN
19	0.4125	AVERAGE	0.275	MARGINAL ITEM	REVISE
20	0.35	DIFFICULT	0.4	EXCELLENT ITEM	RETAIN
21	0.3	DIFFICULT	0.35	REASONABLY GOOD	RETAIN
22	0.3625	DIFFICULT	0.075	NON-DISCRIMINATING	REJECT
23	0.2875	DIFFICULT	0.275	MARGINAL ITEM	REVISE
24	0.2875	DIFFICULT	0.275	MARGINAL ITEM	REVISE
25	0.4625	AVERAGE	0.375	REASONABLY GOOD	RETAIN
26	0.25	DIFFICULT	0.3	REASONABLY GOOD	RETAIN
27	0.4625	AVERAGE	0.625	EXCELLENT ITEM	RETAIN
28	0.5	AVERAGE	0.35	REASONABLY GOOD	RETAIN
29	0.4625	AVERAGE	0.525	EXCELLENT ITEM	RETAIN
30	0.4875	AVERAGE	0.175	POOR ITEM	REJECT

31	0.375	DIFFICULT	0.1	POOR ITEM	REJECT
32	0.2875	DIFFICULT	0.275	MARGINAL ITEM	REVISE
33	0.4125	AVERAGE	0.425	EXCELLENT ITEM	RETAIN
34	0.425	AVERAGE	0.65	EXCELLENT ITEM	RETAIN
35	0.4875	AVERAGE	0.375	REASONABLY GOOD	RETAIN
36	0.2875	DIFFICULT	0.125	POOR ITEM	REJECT
37	0.425	AVERAGE	0.45	EXCELLENT ITEM	RETAIN
38	0.3125	DIFFICULT	0.025	NON-DISCRIMINATING	REJECT
39	0.3625	DIFFICULT	0.425	EXCELLENT ITEM	RETAIN
40	0.475	AVERAGE	0.25	MARGINAL ITEM	REVISE
41	0.2375	DIFFICULT	0.325	REASONABLY GOOD	RETAIN
42	0.4875	AVERAGE	0.325	REASONABLY GOOD	RETAIN
43	0.325	DIFFICULT	0.25	MARGINAL ITEM	REVISE
44	0.3125	DIFFICULT	-0.025	NON-DISCRIMINATING	REJECT
45	0.25	DIFFICULT	0.2	MARGINAL ITEM	REVISE
46	0.3125	DIFFICULT	0.225	MARGINAL ITEM	REVISE
47	0.2625	DIFFICULT	0.275	MARGINAL ITEM	REVISE
48	0.45	AVERAGE	0.4	EXCELLENT ITEM	RETAIN
49	0.325	DIFFICULT	0.1	POOR ITEM	REJECT
50	0.2375	DIFFICULT	0.075	NON-DISCRIMINATING	REJECT

Table 6. Summary of Item Classification

Classification	**Number of Items**	**Percentage**
Retain	19	38%
Revise	17	34%
Reject	14	28%
Total	50	100%

Table 6 summarizes the classification of test items based on the results of the difficulty and discrimination indices. Of the 50 items subjected to analysis, 19 items (38%) were retained, 17 items (34%) were revised, and 14 items (28%) were rejected. The retained items exhibited acceptable levels of difficulty and strong discrimination power, indicating their effectiveness in measuring learners' understanding of concepts related to atomic electronic structure and the Periodic Table.

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Items classified for revision exhibited marginal discrimination or suboptimal difficulty and were subsequently refined in wording and distractor effectiveness. Rejected items showed poor discrimination or extreme difficulty values, rendering them unsuitable for the final instrument. Following this rigorous process of analysis and refinement, the final standardized diagnostic test comprised 36 psychometrically sound items. The internal consistency reliability of the pilot 50-item test was $\alpha = 0.72$, and the finalized 36-item test demonstrated excellent reliability ($\alpha = 0.96$), confirming the robustness of the refined instrument for assessing learners' conceptual understanding. Although the reliability coefficient was high, the retained items addressed multiple competencies and conceptual domains, indicating strong internal consistency without excessive item redundancy.

Performance of Learners on the Standardized Diagnostic Test

Following validation, the finalized 36-item standardized diagnostic test, which demonstrated excellent reliability ($\alpha = 0.96$), was administered to Grade 10 learners to assess their understanding of the Periodic Table of Elements.

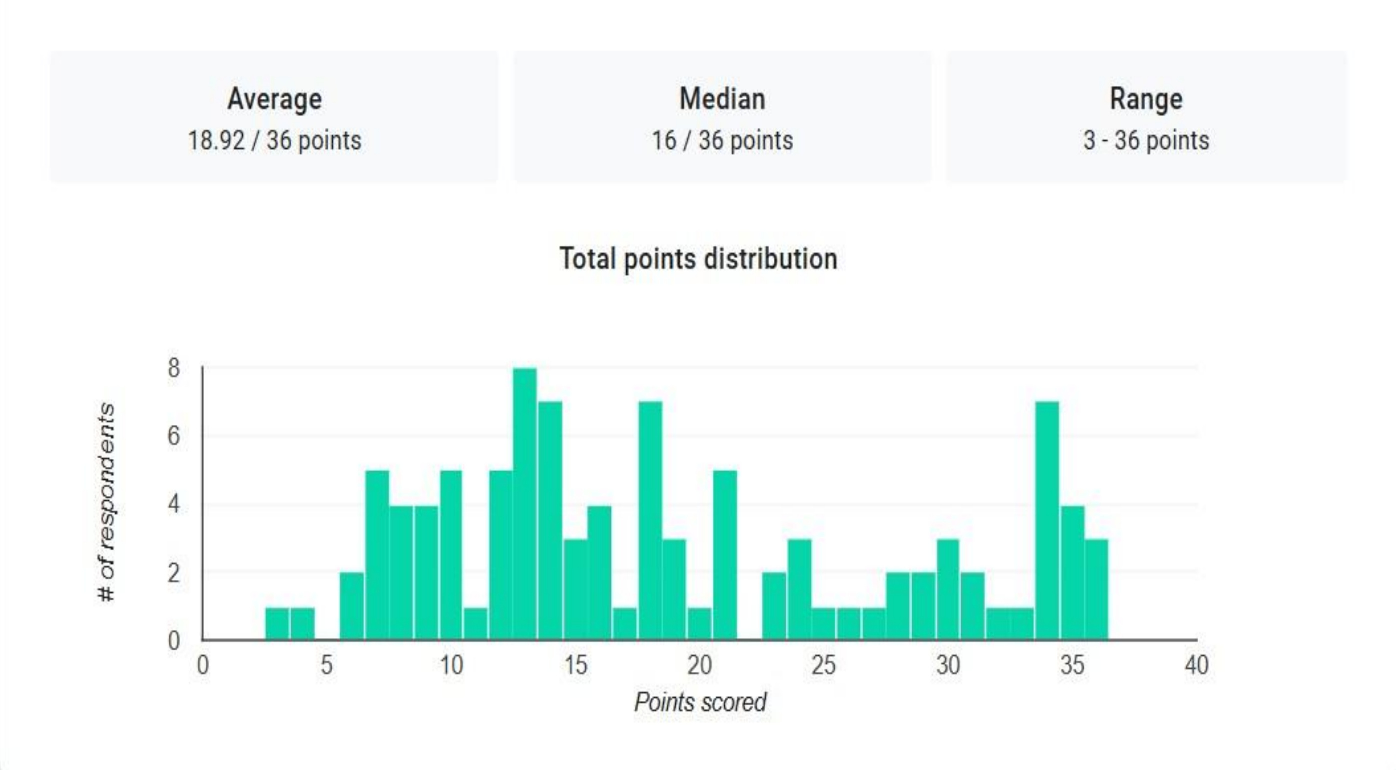

Figure 2. Total Points Distribution

Figure 2 illustrates the distribution of total scores among the respondents, highlighting variability in mastery levels and providing a foundation for identifying least mastered competencies and prevalent misconceptions. The results indicate substantial variability in learner performance, with scores ranging from a minimum of 3 to a maximum of 36 out of 36 points. The mean score of 18.92 and a median of 16 suggest that a considerable proportion of learners performed below the 50% mastery threshold. Score distribution analysis revealed that most learners clustered within the low-to-middle range, whereas only a small number demonstrated high mastery. Despite validation of the instrument for content clarity and curriculum alignment, learners still exhibited significant difficulties, indicating persistent learning gaps. The fragmented distribution of scores suggests that many learners possess only partial or surface-level understanding of Periodic Table concepts, particularly when tasks require application and reasoning. These findings underscore the presence of significant learning gaps that necessitate targeted instructional interventions.

Identified Learning Gaps and Misconceptions on the Periodic Table of Elements

To pinpoint specific learning gaps and misconceptions, an item-level analysis was conducted, focusing on test items with a correct response rate below 50%. These items represent the concepts that learners found most challenging, thereby identifying areas of significant conceptual weakness and highlighting the competencies requiring targeted remediation.

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Table 7. Summary of Least Mastered Competencies and Common Misconceptions on Periodic Table of Elements

MELCS Competency	**Objectives**	**Test Item**	**Total No. of Responses: 100**		**Common Misconceptions**
			% of Correct responses	% of Incorrect responses	
Determine the number of protons, neutrons, and electrons in a particular atom.	Describe how the atomic number and mass number are used to determine the composition of an atom.	5 27	46% 44%	54% 56%	Learners struggle to distinguish between atomic number and mass number, often failing to recognize that the number of protons alone defines an element's identity.
	Differentiate the number of protons, neutrons, and electrons in atoms and ions using information from the Periodic Table.	12 19	34% 47%	66% 53%	Learners erroneously believe that neutrons play a role in balancing electrical charges or that neutrality is a ratio of all particles rather than a proton-electron balance.
	Compute the number of subatomic particles in a given element or ion based on its atomic number and mass number.	21	43%	57%	A significant number of learners believe neutrons can "balance" excess electrons to make an atom neutral.
Trace the development of the periodic table of elements from observations based on similarities of properties of elements.	Identify the contributions of early scientists (Dobereiner, Newlands, Mendeleev, and Moseley) in the classification of elements.	23 34	47% 37%	53 63%	Learners confuse early grouping methods (Triads/Octaves) with modern periodic law, incorrectly attributing atomic number organization to Mendeleev.
Explain the organization and periodic trends of elements in the periodic table.	Explain how electron configuration relates to an element's position in the periodic table.	25	42%	58%	Inability to link valence shell configurations to vertical group placement; learners often confuse period numbers with group numbers.
	Describe and interpret periodic trends such as atomic radius, ionization energy, and electronegativity.	20 30 35	49% 37% 45%	51% 63% 55%	While learners may recognize visual patterns, they lack an understanding of Effective Nuclear Charge and Shielding Effects as the causal factors for trends.

Table 7 summarizes the least mastered competencies and the corresponding misconceptions identified from learner responses. The results reveal persistent difficulties across several foundational areas, including atomic structure, isotopes, atomic neutrality, historical development of the Periodic Table, and periodic trends such as atomic radius, ionization energy, and electronegativity.

Across multiple competencies, learners demonstrated challenges in distinguishing closely related concepts, particularly atomic number versus mass number and the roles of protons, neutrons, and electrons in determining atomic identity and charge. Misconceptions regarding isotopes were also prevalent, with many learners failing to recognize that isotopes share the same atomic number but differ in neutron count. Additionally, confusion was observed concerning the historical basis of element classification, as learners often conflated early grouping methods with the modern periodic law.

For periodic trends, although some learners recognized general patterns, the low percentage of correct responses indicates limited understanding of the underlying causal factors, including effective nuclear charge, electron shielding, and electron configuration. This suggests that learners struggle to bridge the gap between macroscopic symbols and the sub-microscopic reality of atomic interactions (Johnstone, 1991). The inability to articulate principles like Effective Nuclear Charge indicates a reliance on "pattern recognition" rather than an understanding of the electrostatic forces governing atomic behavior. This implies that current instructional practices may be over-emphasizing the 'what' (the trend) rather than the 'how' (the underlying physics), preventing holistic conceptual change and leading to the documented rote memorization.

Collectively, these findings suggest that learners rely heavily on rote memorization rather than conceptual and relational reasoning, emphasizing the need for targeted pedagogical strategies. The identified learning gaps provide an empirical foundation for the instructional implications discussed below.

CONCLUSION AND RECOMMENDATION

The findings of this study reveal that Grade 10 learners exhibit significant learning gaps and misconceptions in their understanding of the Periodic Table of Elements. While some learners were able to recognize surface-level patterns, many struggled with foundational atomic concepts, including differentiating atomic number from mass number, understanding isotopes, and applying principles of atomic neutrality.

Misconceptions were also evident in interpreting periodic trends, particularly regarding effective nuclear charge, shielding effects, and factors influencing reactivity, ionization energy, and electronegativity. These results underscore a prevalent reliance on memorization over conceptual understanding, highlighting the necessity of targeted instructional interventions.

At a policy and curricular level, these findings suggest a need for the Department of Education to consider the formal integration of validated diagnostic tools into the Science curriculum. Standardizing these assessments can help teachers in resource-limited hinterland areas move away from a "one-size-fits-all" approach by allowing them to prioritize data-driven remedial modules. Furthermore, curriculum developers should consider a more explicit pedagogical focus on electrostatic forces earlier in the Junior High School chemistry sequence to provide the necessary foundation for understanding periodic trends beyond mere visual patterns.

In response to these findings, it is recommended that teachers employ visual models, interactive simulations, and guided discussions to clarify abstract concepts and reinforce relational understanding. Regular diagnostic assessments may be implemented to identify misconceptions early and provide timely feedback. Learners should engage in problem-solving exercises and interactive activities that strengthen comprehension of atomic structure and periodic trends. Future research is encouraged to investigate the efficacy of technologyenhanced instructional tools and active learning strategies in addressing learning gaps and promoting sustained conceptual understanding in chemistry education. Additionally, future studies could incorporate inferential or longitudinal approaches to determine how these misconceptions evolve over time and whether specific interventions lead to significant improvements in learning outcomes.

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REFERENCES

1. Bernardo, A. (2019). Students' conceptual challenges in junior high school chemistry in the Philippines. Philippine Journal of Science Education.
2. Bierenstiel, M., & Snow, K. (2019). Periodic universe: A teaching model for understanding the periodic table of the elements. Journal of Chemical Education, 96(7), 1367-1376. https://doi.org/10.1021/acs.jchemed.8b00740
3. Bucat, B., & Mocerino, M. (2009). Learning at the sub-micro level: Structural representations. In J. K. Gilbert & D. Treagust (Eds.), Multiple Representations in Chemical Education (Vol. 4, pp. 11-29). Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-8872-8_2
4. Chowdhury, P. (2022). Learners' misconceptions in periodic table: An analysis of cognitive skills development. Universal Journal of Educational Research, 10(1), 57-66. https://doi.org/10.13189/ujer.2022.100106
5. Cooper, M. M., Williams, L. C., & Underwood, S. M. (2013). An investigation of college chemistry students' understanding of structure–property relationships. Journal of Research in Science Teaching, 50(6), 699-721. https://doi.org/10.1002/tea.21093
6. Cooper, M. M., Underwood, S. M., & Hilley, C. (2017). Investigating student understanding of periodic trends. Journal of Chemical Education.
7. Franco-Mariscal, A. J., Oliva-Martínez, J. M., & Almoraima Gil, M. L. (2015). Students' perceptions about the use of educational games as a tool for teaching the periodic table of elements at the high school level. Journal of Chemical Education, 92(2), 278-285. https://doi.org/10.1021/ed4003578
8. Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics.
9. Proceedings of the National Academy of Sciences, 111(23), 8410-8415. https://doi.org/10.1073/pnas.1319030111
10. Herdien, R. A. (2024). Identification of misconceptions in 10th grade students on atomic structure material. Journal of Chemistry Sciences and Education, 1(02), 50–57. https://doi.org/10.69606/jcse.v1i02.129
11. Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. Journal of Computer Assisted Learning, 7(2), 75-83. https://doi.org/10.1111/j.1365-2729.1991.tb00230.x
12. Mokiwa, H. O. (2017). Reflections on teaching periodic table concepts: A case study of selected schools in South Africa. Eurasia Journal of Mathematics, Science and Technology Education, 13(6), 1563-1573. https://doi.org/10.12973/eurasia.2017.00685a
13. Mulford, D. R., & Robinson, W. R. (2002). An inventory for alternate conceptions among first-semester general chemistry students. Journal of Chemical Education, 79(6), 739. https://doi.org/10.1021/ed079p739
14. National Research Council. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. The National Academies Press.
15. National Research Council. (2012). Discipline-based education research: Understanding and improving learning in undergraduate science and engineering. The National Academies Press.
16. Necor, D. (2018). Exploring students' level of conceptual understanding on periodicity. JPAIR Multidisciplinary Research, 33(1), 136-154. https://doi.org/10.7719/jpair.v33i1.609
17. Salame, I. I., Sarowar, S., Begum, S., & Krauss, D. (2011). Students' alternative conceptions about atomic properties and the periodic table. The Chemistry Educator, 16, 190-194.
18. Sanger, M. J., & Greenbowe, T. J. (2000). Addressing student misconceptions concerning electron flow in aqueous solutions with instruction including computer animations and conceptual change strategies. International Journal of Science Education, 22(5), 521–537. https://doi.org/10.1080/095006900289769

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19. Taber, K. S. (2013). Revisiting the chemistry triplet: Drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. Chemistry Education Research and Practice, 14(2), 156-168. https://doi.org/10.1039/C3RP00012E
20. TIMSS. (2019). TIMSS 2019 international results in science. International Association for the Evaluation of Educational Achievement (IEA).
21. Treagust, D. F. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. International Journal of Science Education, 10(2), 159-169. https://doi.org/10.1080/0950069880100204
22. Yanti, R., & Yasthophi, A. (2024). The analysis of students misconceptions by using four-tier diagnostic test on periodic table of the elements lesson. Jurnal Penelitian Pendidikan Kimia, 13(3). https://doi.org/10.23960/jppk.v13.i3.32640