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Development and Validation of a Digital Prior Knowledge Activation (Pka) Module for Enhancing Grade 10 Learners' Understanding of Gas Laws

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ABSTRACT

This study developed and validated a Digital Prior Knowledge Activation (PKA) Module to enhance Grade 10 learners' understanding of Gas Laws, which is among the least learned competencies in Science 10 Quarter 4 Chemistry. Conducted in selected public secondary schools in Lingig I District, Division of Surigao del Sur, during School Year 2025–2026, the study was anchored on Cognitive Load Theory, Prior Knowledge Activation Theory, and the Cognitive Theory of Multimedia Learning. Specifically, it aimed to identify the least learned competency, develop and validate a Digital PKA Module, determine its effectiveness, assess its acceptability among expert validators, teachers, and learners, identify implementation challenges, and propose enhancements based on the findings. A Descriptive-Developmental Research Design employing quantitative and qualitative approaches was utilized. Data were gathered through district competency monitoring reports, researcher-made pretest and posttest instruments, validation questionnaires, perception surveys, and Focus Group Discussions (FGDs). Data were analyzed using mean, standard deviation, the Wilcoxon Signed-Rank Test, Analysis of Variance (ANOVA), and thematic analysis.

The findings revealed that Gas Laws remained among the least-learned competencies for Grade 10 learners. The developed Digital PKA Module obtained highly acceptable ratings from expert validators and teachers, while learners expressed positive perceptions regarding its usefulness and organization. Field implementation showed a significant improvement in learners' posttest performance compared with their pretest results. Qualitative findings identified challenges related to instructional time, technical and resource limitations, learner support, and the need for additional examples and scaffolding activities. The study concluded that the Digital Prior Knowledge Activation (PKA) Module is an effective, acceptable, and learner-centered instructional intervention that promotes learner readiness, engagement, and conceptual understanding of complex science concepts.

INTRODUCTION

Science education plays a vital role in developing learners' scientific literacy, critical thinking, and problem-solving skills necessary for addressing real-world challenges in a technology-driven society. Within the K–12 curriculum, Science aims to equip learners with competencies that enable them to understand natural phenomena and make informed decisions. Among its disciplines, Chemistry presents unique learning challenges because it involves abstract concepts, scientific relationships, and the interpretation of observable phenomena through microscopic explanations. In Science 10 Quarter 4, learners are expected to explain the relationships among pressure, volume, and temperature using Gas Laws and the Kinetic Molecular Theory. These concepts require learners to connect prior knowledge with new scientific ideas, making meaningful learning dependent on their ability to recall and apply prerequisite concepts. In response to this need, the present study developed and validated a Digital Prior Knowledge Activation (PKA) Module designed to enhance learners' understanding of Gas Laws through interactive and learner-centered learning experiences.

Recent studies highlight the importance of activating prior knowledge and integrating digital learning technologies in science instruction. Prior knowledge activation enables learners to connect existing understanding with new information, thereby improving comprehension, retention, and meaningful learning (Brand *et al.*, 2025; NSW Department of Education, 2024). Likewise, multimedia-supported instruction enhances learner engagement and facilitates the understanding of abstract scientific concepts through visual, verbal, and interactive representations (Lou & Jaeggi, 2020; Mayer, 2024). Studies have further shown that digital learning modules and technology-enhanced instructional materials contribute positively to learners' motivation, participation, and academic achievement in science education (Navarette *et al.*, 2023). Collectively, these findings suggest that combining prior knowledge activation strategies with digital learning resources can support learners' understanding of complex scientific concepts.

Despite the availability of various instructional approaches, Gas Laws remain among the least learned competencies in Science 10. District competency monitoring reports from School Years 2023–2024 to 2025–2026 consistently identified Gas Laws and the Kinetic Molecular Theory as areas of low learner

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mastery (Taglorin *et al.*, 2025). Classroom observations, assessment results, and remediation activities in Lingig I District likewise revealed persistent difficulties in relating particle behavior to gas properties, interpreting graphical representations, and applying gas law principles in problem-solving situations (Talens *et al.,* 2026; Sanchez, 2020). These recurring learning difficulties indicate gaps in learners' conceptual readiness and highlight the need for instructional interventions that intentionally activate prior knowledge before introducing complex Chemistry concepts.

To address this educational concern, the study developed and validated a Digital Prior Knowledge Activation (PKA) Module for Grade 10 learners. The module integrates prior knowledge activation strategies, multimedia learning features, and learner-centered activities to improve conceptual understanding and learning readiness. Through expert validation, field implementation, and evaluation by teachers and learners, the study sought to produce an instructional resource that is effective, acceptable, and responsive to local educational needs. The findings are expected to contribute to the improvement of Science instruction, strengthen interventions for least learned competencies, and provide empirical evidence on the value of prior knowledge activation and digital learning in enhancing learners' understanding of complex Chemistry concepts.

LITERATURE REVIEW

Prior Knowledge Activation and Learning Readiness

Prior knowledge activation plays a critical role in facilitating meaningful learning by helping learners connect existing knowledge with new information. Research has consistently shown that activating prerequisite concepts before instruction enhances comprehension, retention, and learning readiness (Brand *et al.,* 2025; Hattan *et al.*, 2024). According to Brod (2021), prior knowledge serves as a cognitive framework that enables learners to interpret and organize new information more effectively. Similarly, the NSW Department of Education (2024) emphasized that activating prior knowledge through guiding questions, concept maps, and preparatory activities increases learners' confidence, participation, and engagement during instruction. In science education, learners who actively connect previous learning experiences with new concepts demonstrate stronger conceptual understanding and academic performance than those who do not engage in prior knowledge activation activities (Brand *et al.*, 2025). These findings suggest that activating prior knowledge is an essential instructional strategy for improving learners' readiness to engage with complex scientific concepts.

Cognitive Load and Science Learning

The effectiveness of prior knowledge activation is closely linked to learners' cognitive processing during instruction. Cognitive Load Theory posits that learners have limited working memory capacity; therefore, instructional materials should be designed to reduce unnecessary cognitive demands and support schema construction (Sweller, 2020). Research has shown that learners perform better when instructional materials provide structured guidance and scaffolding, particularly when learning abstract scientific concepts (Chen & Kalyuga, 2021). Ouwehand *et al.* (2025) further emphasized that well-designed instructional supports, such as guided sequencing and multimedia scaffolds, help reduce extraneous cognitive load and improve learning outcomes. These findings highlight the importance of designing instructional materials that activate prior knowledge while simultaneously minimizing cognitive overload.

Multimedia Learning and Digital Visualization in Chemistry

Chemistry learning often requires learners to connect macroscopic observations, microscopic particle behavior, and symbolic representations. Consequently, multimedia-supported instruction has become an effective approach for enhancing conceptual understanding. Mayer (2024) explained that learners acquire scientific concepts more effectively when words, images, animations, and interactive elements are meaningfully integrated. Similarly, Abdinejad *et al.* (2021) reported that digital visualizations and interactive learning environments help learners understand abstract chemistry concepts by making invisible processes more observable. Studies have likewise demonstrated that simulations, animations, and multimedia learning tools improve learners' engagement, motivation, and achievement in science education (Antonio & Castro, 2023; Vogt *et al.,* 2020). These findings support the integration of multimedia features into instructional materials designed to improve learners' understanding of Gas Laws.

Instructional Material Development and Validation

The development of effective instructional materials requires a systematic design process that aligns learning objectives, content, instructional activities, and evaluation procedures. The ADDIE Model remains one of the most widely used instructional design frameworks for developing educational resources. Studies have shown that instructional materials developed through the ADDIE process demonstrate high levels of quality, effectiveness, and acceptability (Arevalo *et al.,* 2023; Alvarez & Baraquia, 2023). Similarly, Agbunag (2022) reported that contextualized and technology-supported learning materials improved learner engagement and academic performance in science. These findings suggest that systematically developed instructional materials can serve as effective interventions for addressing identified learning difficulties and supporting meaningful learning experiences.

Research Gap

Although previous studies have established the value of prior knowledge activation, cognitive load management, multimedia learning, and instructional material development in science education, these concepts have largely been examined independently. Furthermore, limited empirical evidence exists regarding the development and validation of a Digital Prior Knowledge Activation (PKA) Module specifically designed for Grade 10 Gas Laws in Philippine public secondary schools. Existing studies have focused primarily on general science instruction, multimedia learning, or module development without integrating prior knowledge activation strategies into a technology-supported instructional intervention. This gap highlights the need for a learner-centered and evidence-based instructional material that combines prior knowledge activation, multimedia learning principles, and systematic instructional design to improve learners' conceptual understanding of Gas Laws.

MATERIALS AND METHODS

Research Design

This study employed a mixed-methods approach utilizing a Developmental-Evaluative Research Design (DERD) and a One-Group Pretest–Posttest Quasi-Experimental Design. The developmental component focused on the design, development, validation, and evaluation of a Digital Prior Knowledge Activation (PKA) Module intended to enhance Grade 10 learners' understanding of Gas Laws. The quasi-experimental component was used to determine the effectiveness of the module through the comparison of learners' pretest and posttest scores following its implementation.

Research Locale and Participants

The study was conducted in three public secondary schools in Lingig I District, Division of Surigao del Sur, Philippines, during School Year 2025–2026. Participants included 112 Grade 10 learners who participated in the field try-out and 10 Grade 10 Science teachers who evaluated the developed module. The learners were drawn from Lingig National High School (n = 46), Margarita K. Yusingco National High School (n = 32), and Pagtilaan Integrated School (n = 34). In addition, the module underwent expert evaluation by five content validators and five digital module validators selected through purposive sampling based on their expertise in science education, instructional material development, and learning resource evaluation.

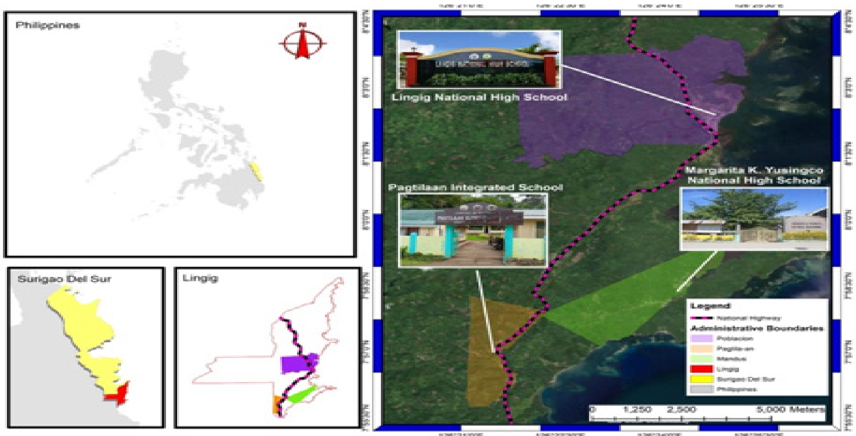

Figure1: Location Map of the Study

Research Instruments

The study utilized four instruments: (1) the researcher-developed Digital Prior Knowledge Activation (PKA) Module, (2) a 20-item researcher-made Achievement Test administered as pretest and posttest, (3) expert validation questionnaires, and (4) teacher and learner evaluation questionnaires. The achievement test was developed using a Table of Specifications and underwent face and content validation by qualified experts. Pilot testing yielded Cronbach's alpha coefficients of 0.88 for the Achievement Test, 0.83 for the Student Evaluation Questionnaire, and 0.70 for the Teacher Evaluation Questionnaire, indicating acceptable to high reliability.

Data Collection Procedure

The development of the module followed the ADDIE instructional design framework consisting of Analysis, Design, Development, Implementation, and Evaluation phases. The least learned competency was identified through district competency monitoring reports and Mean Percentage Scores (MPS). Following validation and reliability testing, the pretest was administered to the learner participants. The Digital PKA Module was then implemented during regular classroom instruction. After implementation, the posttest and evaluation questionnaires were administered. Focus Group Discussions (FGDs) were subsequently conducted with selected teachers and learners to gather qualitative data regarding implementation challenges and recommendations for improvement.

Data Analysis

Quantitative data were analyzed using Mean Percentage Score (MPS), frequency and percentage, weighted mean, standard deviation, Wilcoxon Signed-Rank Test, and One-Way Analysis of Variance (ANOVA). Qualitative data gathered through Focus Group Discussions were analyzed using Braun and Clarke's (2006) Thematic Analysis Framework to identify recurring themes related to the implementation of the module. Statistical analyses were performed at the 0.05 level of significance.

RESULTS AND DISCUSSION

Identification of the Least Learned Competency

The analysis of district competency monitoring reports from School Years 2023–2024 to 2025–2026 revealed that Gas Laws and the Kinetic Molecular Theory consistently emerged as the least learned competency among Grade 10 learners. This finding indicates persistent difficulties in understanding the relationships among pressure, volume, and temperature and in explaining gas behavior using particle-level representations.

The result supports the findings of Taglorin *et al.* (2025), who identified Chemistry concepts as among the least mastered competencies in secondary science. Similarly, Talens *et al.* (2026) reported that learners often struggle to develop accurate mental representations of gas behavior, resulting in misconceptions and low conceptual understanding.

Table 1: Top Three Least Learned Competencies in Science 10 Based on District Competency Monitoring Reports (S.Y. 2023–2024 to S.Y. 2025–2026)

Rank	Learning Competency Code	Learning Competency	Remarks
1	S10MT-IVa-b-21	Investigate the relationship between: (1) volume and pressure at constant temperature of a gas; (2) volume and temperature at constant pressure of a gas; and explain these relationships using the Kinetic Molecular Theory.	Consistently Identified as the Least Learned Competency
2	S10MT-IIIh-j-30*	Apply the principles of conservation of mass to chemical reactions.	Least Learned Competency
3	S10LT-IIId-e-34*	Recognize the major categories of biomolecules such as carbohydrates, lipids, proteins, and nucleic acids.	Least Learned Competency

Source: Lingig I District Competency Monitoring Reports (S.Y. 2023–2024 to S.Y. 2025–2026)

Development of the Digital Prior Knowledge Activation (PKA) Module

Figure 2 illustrates the ADDIE instructional design process utilized in the development of the Digital Prior Knowledge Activation (PKA) Module. The process began with the identification of the least learned competency, followed by the design and development of instructional materials, field implementation, and evaluation through expert validation, learner and teacher feedback, and module enhancement.

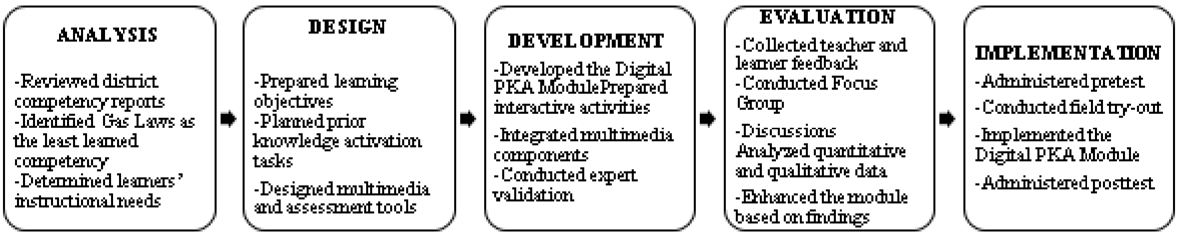

Figure 2: Development Process of the Digital Prior Knowledge Activation (PKA) Module

Effectiveness of the Digital Prior Knowledge Activation (PKA) Module

The results revealed a substantial improvement in learners' performance following exposure to the Digital PKA Module. The mean score increased from 7.97 during the pretest to 14.34 during the posttest. Likewise, the Mean Percentage Score improved from 39.85% to 71.70%.

The Wilcoxon Signed-Rank Test yielded a p-value lower than the 0.05 level of significance, indicating a statistically significant difference between the pretest and posttest scores. Therefore, the null hypothesis was rejected.

These findings suggest that the Digital PKA Module effectively enhanced learners' understanding of Gas Laws. The results support the work of Brand *et al.* (2025), who emphasized the importance of prior knowledge activation in improving learning readiness and conceptual understanding. Likewise, Mayer (2024) highlighted that multimedia-supported instruction facilitates deeper learning and improved academic performance.

Table 2: Pretest and Posttest Performance of Learners

Group	Pretest Mean Score	MPS (%)	Descriptive Equivalent	Posttest Mean Score	MPS (%)	Descriptive Equivalent
Group A (n = 46)	8.63	43.15%	Average Mastery	14.67	73.35%	Moving Towards Mastery
Group B (n = 32)	7.38	36.90%	Average Mastery	14.50	72.50%	Moving Towards Mastery
Group C (n = 34)	7.91	39.55%	Average Mastery	13.85	69.25%	Moving Towards Mastery
Overall Average	**7.97**	**39.85%**	**Average Mastery**	**14.34**	**71.70%**	**Moving Towards Mastery**

Table 3: Wilcoxon Signed-Rank Test Results

	p-value	Decision	Conclusion
Pre-Test vs Post-Test	0.000	Reject Ho	There is a significant difference

Acceptability of the Digital Prior Knowledge Activation (PKA) Module

The developed module received favorable evaluations from expert validators, teachers, and learners. Expert validators rated the module as Highly Acceptable, obtaining an overall mean of 4.66. Teachers likewise provided highly favorable ratings, while learners expressed positive perceptions regarding the usefulness, organization, and interactive features of the module.

These findings indicate that the Digital PKA Module possesses high instructional quality, usability, and classroom applicability. The positive evaluations further support the principles of multimedia learning, which emphasize learner engagement through the integration of visual, verbal, and interactive instructional elements.

Table 4: Summary of Acceptability Ratings of the Digital PKA Module

Indicators	Weighted Mean	Standard Deviation	Adjectival Description
Content	4.68	0.51	Highly Acceptable
Format	4.64	0.53	Highly Acceptable
Presentation and Organization	4.64	0.49	Highly Acceptable
Accuracy and Up-to-Datedness of Information	4.72	0.42	Highly Acceptable
Technological Features	4.60	0.53	Highly Acceptable
Overall Weighted Mean	**4.66**	**0.49**	**Highly Acceptable**

Differences in the Validation Ratings of Learners, Teachers, and Expert Validators

Analysis of Variance (ANOVA) revealed significant differences among the ratings provided by expert validators, teachers, and learners across all evaluation indicators. The highest variation was observed in the area of Accuracy and Clarity of Information.

The significant differences may be attributed to variations in professional expertise, instructional experience, and familiarity with curriculum standards among the respondent groups. Despite these differences, all groups provided favorable ratings, indicating broad acceptance of the developed instructional material.

Table5: ANOVA Results on the Validation Ratings of the Three Groups of Respondents

Indicator	Group	Mean	p-value	Conclusion
Content	Learners	4.18	0.0086	There is a Significant Difference
	Teachers	4.40		
	Experts	4.68		
Format	Learners	4.17	0.0266	
	Teachers	4.36		
	Experts	4.64		
Presentation and Organization	Learners	4.13	0.0064	
	Teachers	4.40		
	Experts	4.64		
Accuracy and Clarity of Information	Learners	4.13	0.00002	
	Teachers	4.50		
	Experts	4.72		
Technological Features	Learners	4.16	0.0254	
	Teachers	4.34		
	Experts	4.60		

Legend: Level of Significance = 0.05

Table 6: Themes and Subthemes on the Prevailing Challenges Encountered During the Implementation of the Digital Prior Knowledge Activation (PKA) Module

Theme	Subthemes
Time Management Constraints	Limited time for activity completion; Need for extended processing time
Need for Additional Instructional Support	Difficulty understanding instructions; Need for teacher guidance and scaffolding
Technical and Resource Limitations	Device availability concerns; Minor technical issues during implementation
Need for Enriched Learning Resources	Additional examples and practice activities; Clarification of unfamiliar terms

Challenges Encountered During Implementation

Qualitative analysis of the Focus Group Discussions generated four major themes: Time Management Constraints, Need for Additional Instructional Support, Technical and Resource Limitations, and Need for Enriched Learning Resources.

Participants reported that limited instructional time occasionally affected the completion of activities. Teachers and learners likewise emphasized the need for additional guidance, examples, and scaffolded learning activities to strengthen conceptual understanding. Some participants also noted concerns regarding device availability and technological resources.

Although these challenges were identified, participants generally perceived them as manageable and did not consider them major barriers to learning. Instead, the findings provide valuable insights for refining future versions of the module and enhancing classroom implementation.

Enhanced Digital Prior Knowledge Activation (PKA) Module

Based on the quantitative and qualitative findings, several enhancements were incorporated into the module. These improvements included the addition of contextualized examples, scaffolded learning activities, glossaries of scientific terms, flexible implementation options, printable learning resources, and teacher facilitation guides.

The enhanced module retained the validated instructional components while addressing concerns raised by learners and teachers. These refinements were intended to improve usability, accessibility, learner support, and overall instructional effectiveness.

CONCLUSION

The study confirmed that Gas Laws remained among the least learned competencies in Science 10, highlighting persistent conceptual difficulties among Grade 10 learners in understanding the relationships among pressure, volume, temperature, and the Kinetic Molecular Theory. In response to this learning gap, a Digital Prior Knowledge Activation (PKA) Module was developed using established learning theories and instructional design principles. The successful development of the module demonstrates the potential of integrating prior knowledge activation strategies and multimedia learning features into instructional materials that address identified learning needs.

The findings further revealed that the Digital PKA Module significantly improved learners' academic performance and conceptual understanding of Gas Laws. Expert validators, teachers, and learners evaluated the module favorably, indicating its acceptability in terms of content quality, organization, accuracy, clarity of information, and technological features. The positive evaluations suggest that the module is a practical, learner-centered, and technology-supported instructional resource that promotes engagement and meaningful learning.

Although challenges related to instructional time, learner support, and resource availability were identified during implementation, these concerns were generally manageable and provided valuable insights for module enhancement. The enhanced Digital Prior Knowledge Activation (PKA) Module therefore represents a locally responsive and evidence-based instructional intervention that can support the improvement of least learned competencies in Science. The findings likewise contribute to the growing body of literature on prior knowledge activation, multimedia learning, and instructional material development in science education.

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