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ENHANCING HIGHER-ORDER THINKING SKILLS IN CHEMISTRY EDUCATION: A VALIDATED CANVA-IBL-STEM MODEL FOR STOICHIOMETRY LEARNING

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ABSTRACT

Developing Higher Order Thinking Skills (HOTS) remains a major obstacle in the global drive for STEM education in the twenty-first century, especially in complex subjects like stoichiometry. Although Inquiry-Based Learning with STEM (IBL-STEM) fosters critical thinking and Canva is frequently used for educational design, no previous study has combined these strategies to solve the conceptual challenges of stoichiometry. This study aimed to create and verify a Canva-based stoichiometry teaching resource and examine its effectiveness in improving chemistry students' HOTS. We created interactive Canva modules with guided inquiry tasks, molecular visualization, and HOTS assessment using the ADDIE paradigm (Analysis, Design, Development, Implementation, Evaluation). The materials were tested with 62 students using pre-test/post-test comparisons and validated by three chemistry education specialists (mean feasibility scores: 4.71 for content and 4.74 for media). With post-test scores (76.94 ± 6.61) significantly surpassing pre-test findings (35.71 ± 6.36), the intervention significantly improved HOTS (mean gain: 41.23 ± 9.33, $p < 0.001$). The results of this study indicate that the Canva-IBL-STEM model is valid for implementation in stoichiometry learning and has been shown to improve students' HOTS abilities. The findings provide educators with a model for inquiry-driven, technology-enhanced learning that connects design tools with profound conceptual knowledge.

Keywords: canva for education; HOTS; IBL-STEM; stoichiometry; digital learning materials

INTRODUCTION

In the dynamic evolution of 21st-century education, the development of Higher Order Thinking Skills (HOTS) has become a strategic imperative, especially within the realm of science, technology, engineering, and mathematics (STEM) (Agussuryani et al., 2022; Irdalisa et al., 2024; Pineda et al., 2025). These skills, encompassing analysis, evaluation, and creation, are essential not only for academic success but also for preparing learners to confront complex, real-world challenges. In chemistry education, HOTS plays a pivotal role in facilitating deep conceptual understanding, particularly in cognitively demanding topics such as stoichiometry. Despite the central importance of stoichiometry in general chemistry curricula, students often demonstrate weak conceptual transfer, superficial reasoning, and difficulty applying core concepts such as

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mole ratios and the law of conservation of mass in new or unfamiliar contexts (Panggabean et al., 2023; Dah et al., 2024).

Developing students' HOTS in the STEM domain, especially in chemistry education, is urgently needed to prepare human resources to achieve the Sustainable Development Goals (SDGs). Educators must be able to integrate SDG values and competencies into core competencies and design learning scenarios that enhance students' critical thinking and HOTS skills in addressing sustainable development issues (Khoiri et al., 2022; Griebeler et al., 2022; Filho et al., 2023). Educating and preparing future generations with the fundamentals encompassed by the SDGs is crucial (Zickafoose et al., 2024). To achieve this, new or existing learning methodologies must be adapted to promote sustainable development (Urbančič et al., 2019; Zeng et al., 2020; Sánchez & Sanchis, 2021; Nwogu et al., 2021).

This is because the SDGs framework places education in a central role as a catalyst for transformational change. Education holds enormous potential, as reflected in SDG 4, namely quality education (Kioupi & Voulvoulis, 2020; Kiely et al., 2021; Ribeiro et al., 2023; Koçulu & Topçu, 2024). Education for the SDGs is part of Target 4.7, which aims to ensure that students acquire the knowledge and skills needed to meet their needs using a balanced and integrated approach to the economic, social, and environmental dimensions of sustainable development and is understood as a crucial means to achieving all other SDGs (Liu et al., 2020; Bekteshi & Xhaferi, 2020; Obrecht et al.. 2021; Nguyen et al., 2024).

Recent data suggest that over 60% of undergraduate students struggle to solve stoichiometric problems when faced with real-world cases or non-routine formats, pointing to a pedagogical gap in current instruction (Gulacar et al., 2022; Panggabean et al., 2023; Zhan et al., 2023). While instructional models such as Inquiry-Based Learning (IBL) and STEM integration have shown promise in enhancing critical thinking and engagement in chemistry classrooms, many implementations still lack the technological scaffolding necessary to support cognitive processing in abstract learning domains. The following are the results of a meta-analysis of several previous studies related to the implementation of IBL STEM (Table 1).

Table 1. Meta-Analisis IBL STEM

No.	Identity	Level of Education	Competency	Results
1	Paramita et al. (2020)	Senior High School	Conceptual understanding and argumentation skills	The application of guided inquiry within a STEM approach affects students' conceptual understanding and argumentation skills.
2	Fitriansyah et al. (2021)	Junior High School	Attitude and Scientific Work	The STEM approach in the guided inquiry learning model is superior at improving students' scientific attitudes and scientific work compared to not using STEM.
3	Santoso & Arif (2021)	Junior High School	Critical Thinking Skills	The inquiry model, combined with the STEM approach, has a significant influence on students' critical thinking skills.
4	Panggabean et al. (2023)	College	LOTS and HOTS	Implementing the IBL-STEM model can improve students' LOTS and HOTS.
5	Pohan et al. (2024)	College	Perception and Response	Learning experiences using STEM-based inquiry learning models have a positive impact on students' perceptions and responses.

In parallel, the adoption of visual digital tools like Canva in educational contexts has gained traction. Studies show that Canva enhances visual literacy, creativity, and engagement across disciplines (Catubig et al., 2024; Astaño, 2025). However, its use in science learning often remains superficial, limited to decorative or presentation purposes, without being deeply integrated into inquiry-based STEM pedagogies (Deák et al., 2021; Morris, 2025).

This disconnect highlights a significant research gap. Although IBL-STEM models and digital design tools have demonstrated effectiveness individually, few studies have systematically integrated them into a unified instructional model that supports HOTS development in chemistry. The existing literature lacks robust models that position Canva not merely as an accessory but as a visual scaffold integrated into the inquiry cycle, aligned with cognitive load theory and constructivist learning principles (Sweller et al., 2019; Bhattacharya & Mohalik, 2021; Antonio & Prudente, 2024). Moreover, the ADDIE model, widely acknowledged for its structured development process in digital learning, has rarely been used to validate such Canva-integrated inquiry learning frameworks (Alenezi, 2023; Gourlay, 2021; Salsabila et al., 2020).

The novelty of this study lies in its effort to fill that theoretical and practical void. By developing and validating an integrated Canva-IBL-STEM model, this research bridges the divide between design technology and scientific reasoning, offering a replicable approach to fostering HOTS in stoichiometry learning. It does not merely support prior findings but extends them by embedding a visual-inquiry scaffold within a digital learning platform, allowing students to construct knowledge actively while reducing extraneous cognitive load. This study positions itself as both a reinforcement and an advancement of previous research, supporting the effectiveness of IBL-STEM while correcting the underutilization of Canva in conceptual learning (Kırıcı & Bakırcı, 2021; Ilyas et al., 2023; Firdayanti et al., 2024).

Based on this foundation, the present research aims to (1) develop and validate Canva-based teaching materials using the IBL-STEM approach for stoichiometry, and (2) evaluate their effectiveness in improving students' HOTS. This study is expected to make theoretical contributions to digital pedagogy in science education and to offer practical implications for enhancing chemistry instruction through technology-enhanced inquiry frameworks. Moreover, the rapid rise of AI and visual communication demands that education systems prioritize not only analytical reasoning but also creative expression (Reyes & Villanueva, 2024; Catahan et al., 2025). Employers increasingly value creativity, with 85% of hiring managers asserting it will become even more critical in an AI-driven workplace. However, many graduates feel underprepared in this regard. Such findings underscore the urgent need to embed creativity-enhancing tools like Canva into the curriculum not as superficial add-ons, but as integral components of cognitive scaffolding in STEM learning contexts (Dool et al., 2021; Huang et al., 2021).

Indonesia's own experience provides supporting evidence – studies on vocational and elementary education demonstrate that Canva-based media significantly improves student motivation, creativity, and learning outcomes (Sutiani et al., 2021; Kuang et al., 2022). For instance, Canva-infographic tools based on ADDIE development increased conceptual understanding and demonstrated high feasibility (>90%) in blended science learning at the junior high level (Feng & Sangsawang, 2023; Abuhassna et al., 2024). While these contexts confirm Canva's potential as instructional media, its application in higher education chemistry remains sparse, especially within inquiry-driven models.

In contrast, inquiry-based learning integrated within STEM frameworks has shown strong potential to foster HOTS in science domains. Research indicates that IBL-STEM interventions mediate significant increases in critical thinking, problem-solving, and scientific reasoning in chemistry education (Kırıcı & Bakırcı, 2021; Kuang et al., 2022). However, even well-validated IBL-STEM models lack integration with powerful digital visual scaffolding tools. Canva's capabilities for infographic creation, molecular visualization, guided inquiry, and collaborative design offer an underexploited avenue in higher-education chemistry pedagogy. Prior educational technology reviews suggest that while Canva boosts visual literacy and engagement, its application is often ornamental rather than pedagogically transformative (Dare et al., 2021; Yunita et al., 2024).

Thus, the existing literature reveals a pedagogical gap: although IBL-STEM and digital design tools like Canva are each effective in their own domains, no existing study has systematically merged them into a validated instructional model specifically targeting HOTS development in stoichiometry learning. This gap constitutes both a theoretical and practical opportunity. Our research addresses this void by constructing a Canva IBL STEM instructional model guided by the ADDIE design framework. Unlike previous works in which Canva serves as a peripheral visualization tool, here it is embedded centrally within the inquiry cycle as a visual scaffold that reduces extraneous cognitive load (Sweller et al., 2019; Klepsch & Seufert, 2020). It supports constructivist knowledge building and fosters collaborative design activities aligned with student engagement (Theofani & Sediyono, 2022; Bhardwaj et al., 2025).

Furthermore, this research positions itself relative to prior findings by both reinforcing their outcomes and extending their limitations. We support earlier claims of IBL-STEM effectiveness (Kırıcı & Bakırcı, 2021; Panggabean et al., 2023) while addressing the critique that digital tools are underutilized for scaffolding high-order cognition and correcting this by validating Canva as an essential pedagogical medium, not a decorative one. Thus, this model both consolidates prior evidence and innovates beyond it. Ultimately, this study aims to (a) develop and validate Canva-based teaching materials using an IBL STEM model for stoichiometry and (b) evaluate their effectiveness in enhancing HOTS skills among undergraduate chemistry students. Through expert validation and pre-test/post-test comparisons, the study seeks to provide a replicable pedagogical framework that bridges visual design and inquiry-based learning, contributing to both theory and practice in digital chemistry education.

In addition, several recent meta-analyses confirm the robust impact of inquiry-integrated STEM strategies on students' higher-order and creative thinking skills. For STEM-guided inquiry in science learning, a high effect size ($g = 0.99$) was found, indicating that the model significantly improved 21st-century thinking dispositions among students (Abuhassna et al., 2024). A meta-analysis also showed that inquiry-based approaches across science disciplines resulted in substantial improvements in HOTS (Antonio & Prudente, 2024). These findings support the effectiveness of IBL-STEM in educational contexts but also underscore the need for visual scaffolds to help learners manage complex cognitive loads.

At the same time, studies on guided inquiry in chemical education emphasize the importance of scaffolded support. Previous research on acid-base topics has shown that guided inquiry worksheets yield significantly higher HOTS gains than textbook-based instruction (Mawardi et al., 2020). Other research has also reported significant increases in chemical literacy and cognitive reasoning after guided inquiry on equilibrium topics (Priyasmika & Yuliana, 2021). These studies affirm the pedagogical strength of inquiry-based methods but largely lack integration with digital design tools such as Canva, creating a gap that this study addresses. Moreover, recent efforts to develop IBL-STEM models explicitly for chemistry education confirm the academic need for this research. Panggabean, Silitonga, and Gultom created a chemical literacy-based IBL-STEM model to improve LOTS and HOTS in stoichiometry learning and reported statistically significant results using the ADDIE design (Panggabean et al., 2024). Building on this foundation, the present study incorporates the validated Canva platform as a visual-inquiry scaffold to deepen cognitive engagement in abstract stoichiometry concepts.

In contrast to these previous models, the current research situates Canva not merely as an aesthetic or presentation tool but as a core component embedded in the learning process. Sweller et al. (2019) and Klepsch & Seufert (2020) also emphasize that appropriately designed visual scaffolds can reduce irrelevant cognitive load and improve schema construction, especially in complex domains such as chemistry (Sweller et al., 2019; Klepsch & Seufert, 2020). By aligning Canva's affordances with the IBL-STEM structure and ADDIE development cycle, this study offers a pedagogical innovation that is evidence-based and theoretically grounded.

This research also responds to critiques that inquiry-based methods may overload working memory or lack sufficient guidance, particularly among less experienced learners (Orosz et al., 2022; Muhamad Dah et al., 2024). Guided inquiry, when scaffolded effectively, supports learner autonomy while preventing misconception and cognitive breakdown (Feyzioğlu & Demirci, 2021). In our model, Canva visuals are integrated into guided inquiry phases to ensure students engage in conceptual reasoning rather than simplistic calculations, while still receiving structured prompts and feedback.

Positioned within this literature, our study both reinforces and extends existing research. It corroborates the efficacy of IBL-STEM in chemistry pedagogy (Panggabean et al., 2024; Yunita et al., 2024) while simultaneously addressing limitations in visual tool integration and cognitive scaffolding. By validating a Canva-based IBL-STEM instructional model via expert review and statistical testing with students (mean feasibility scores: content = 4.71, media = 4.74; mean HOTS gain = 41.23 ± 9.33, $p < 0.001$), this approach advances both theory and classroom practice.

Facing complex sustainability challenges requires an integrated approach to thinking and learning, making it urgent to develop and cultivate higher-order thinking skills in students. Several previous studies have also identified a research gap in these efforts. Hence, this research seeks to develop and validate Canva-integrated teaching materials for stoichiometry using an IBL-STEM framework grounded in the ADDIE model, and to assess their effectiveness in enhancing HOTS among chemistry undergraduates. Through expert validation and pre test/post test comparison, it aims to deliver a replicable instructional model that bridges digital visual design, guided inquiry, and scientific reasoning. This research also aims to support and correct several previous research findings. This state-of-the-art research also has value by integrating IBL, STEM, and the Canva application into the learning process to improve students' HOTS in stoichiometry. Ultimately, this research helps close the research gap and offers practical insights for digital-era chemistry education that foster deep conceptual understanding and advanced thinking skills.

METHODS

This study employed a Research and Development (R&D) design based on the ADDIE model, a systematic instructional design framework comprising five phases: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was chosen for its adaptability to educational innovation and its suitability for producing validated instructional products (Abuhassna et al., 2024). The methodology was modified by integrating the Canva digital visual design platform within the instructional materials to support students' conceptual understanding and enhance higher-order thinking skills (HOTS). This integration represents an innovative adaptation of the traditional ADDIE approach, in which Canva was not merely used as an aesthetic tool but as a scaffold embedded throughout the instructional cycle.

During the analysis phase, a needs assessment was conducted using curriculum analysis, preliminary literature review, and unstructured interviews with lecturers and students. The findings revealed persistent conceptual difficulties among learners in stoichiometry, particularly in mole-mass conversions and proportional reasoning. These difficulties were compounded by low performance on HOTS-based chemistry assessments, underscoring the need for learning materials that support both content understanding and cognitive development. These findings aligned with previous research indicating that students often struggle with abstract chemical concepts unless supported by appropriate scaffolding (Manullang et al., 2021).

The design phase involved constructing a module structure aligned with inquiry-based learning (IBL) principles integrated into STEM contexts. The materials were mapped against HOTS indicators analysis, evaluation, and creation, based on Bloom's revised taxonomy (Rajendran et al., 2023; Sam, 2024). Canva was selected as the core digital platform to visualize molecular representations, procedural steps, and contextual problem-solving scenarios. This phase also included formulating learning outcomes, selecting media components, and determining assessment criteria.

The development phase encompassed the creation of Canva-based learning modules that integrated inquiry-based prompts, STEM-relevant problems, and HOTS-driven assessment items. These learning materials were subjected to expert validation involving two chemistry education specialists and one instructional media expert. The validation instruments were adapted from the Indonesian Ministry of Education's criteria for learning media feasibility, covering content relevance, instructional clarity, and media effectiveness. Based on the experts' suggestions, several modifications were made to improve instruction clarity, the visual layout, and the alignment between inquiry tasks and expected learning outcomes. These revisions strengthened the materials' usability and pedagogical coherence.

The implementation phase involved a classroom trial conducted at the Department of Chemistry Education, Universitas Negeri Medan, during the 2023–2024 academic year. The implementation stage uses a research design, namely a One-Group Pretest-Posttest Design, involving one class as the experimental class, to determine the effectiveness of Canva-based teaching materials using the IBL-STEM approach for stoichiometry learning. A total of 62 second-year students (1 class) were selected using the cluster random sampling method via a drawing process conducted 3 times from the five existing classes. The implementation process took place over three structured meetings during the stoichiometry unit. Students were encouraged to analyze problem situations, evaluate procedural alternatives, and generate chemical representations or calculations using inquiry-supported visual content. The process of implementing a Canva-based module using an IBL-STEM approach to Stoichiometry learning is visualized in the flowchart shown in Figure 1.

During the evaluation phase, both formative and summative evaluations were conducted (Cahyadi, 2019). The formative evaluation consisted of expert reviews and pilot feedback, which led to revisions in layout and task sequencing. The summative evaluation used a pre-test and post-test design to assess improvements in students' HOTS. The test consisted of 40 multiple-choice items, categorized under C4 (analyzing), C5 (evaluating), and C6 (creating) according to Bloom's taxonomy. These instruments were constructed and validated before the trial. Data from the pre-test and post-test were analyzed using descriptive statistics and paired-sample t-tests in SPSS version 22 (Ghozali, 2020) to test the effectiveness of HOTS enhancement. This approach was selected for its appropriateness in detecting statistically significant improvements in matched samples. Statistically, the Canva-IBL-STEM learning media is declared effective in increasing students' HOTS if the t-value > t-table or the probability value (sig.) < 0.05. In addition, normality testing was performed using the Kolmogorov–Smirnov test to confirm the appropriateness of parametric analysis.

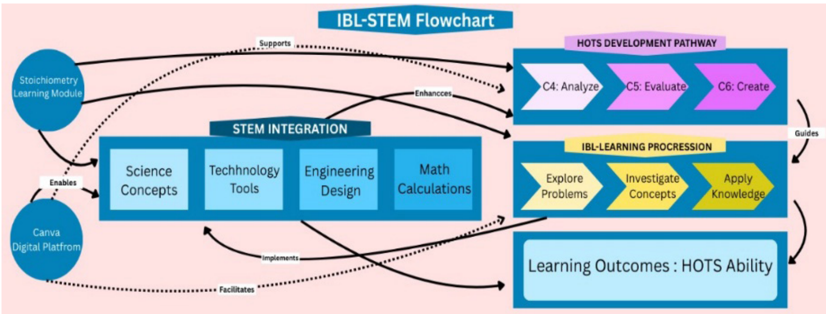

Figure 1. Flowchart of the Stoichiometry Learning Process Based on the Canva-IBL-STEM Model

The combination of expert validation, iterative design revision, and statistical analysis ensured both the pedagogical quality and empirical validity of the developed Canva-IBL-STEM model. This study maintained ethical standards by securing informed consent from all student participants, with formal approval provided by institutional authorities. The methodological rigor and practical relevance of this research provide a strong foundation for implementing digital inquiry-based STEM models in chemistry education that foster deep conceptual understanding and higher-order thinking.

RESULTS AND DISCUSSION

The Canva-IBL-STEM learning materials developed in this study underwent a structured validation process involving three expert validators: two in chemistry education and one in instructional media. Each expert evaluated the materials based on content feasibility, media quality, clarity of language, accuracy of chemical concepts, integration with inquiry-based learning, and alignment with HOTS indicators. Throughout the intervention, students engaged with Canva-based modules that guided them through inquiry cycles: orientation, questioning, data exploration, interpretation, and conclusion drawing (Figure 2).

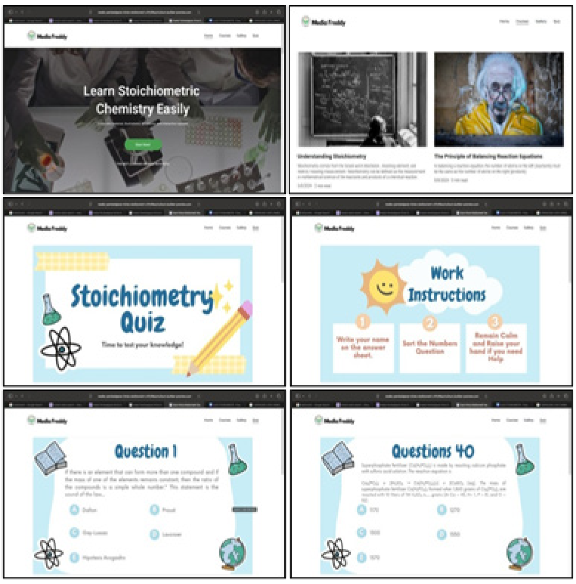

Figure 2. General chemistry Teaching Tools Using the IBL-STEM Approach and Canva to Teach Stoichiometry

The results of the evaluation (validation) of the Canva-IBL-STEM learning media by the expert material validator team are summarized in Table 2.

Table 2. Results of Evaluation (Validation) of Learning Tools Based on Real Criteria

Assessment aspects	Validator (mean score)			Total mean	Criteria
	I	II	III		
Contents of the material	4.75	4.50	4.88	4.71	Valid
Presentation of material	4.75	4.63	4.88	4.75	Valid
Language	4.50	4.67	4.50	4.56	Valid
Use of learning models	4.83	4.83	4.67	4.78	Valid
HOTS assessment	4.67	4.83	4.83	4.78	Valid
Total mean score on the material aspect				4.71	valid

Table 2 shows that the mean content validation score was 4.71 out of 5, indicating a "very valid" category, with high agreement across all indicators—particularly in conceptual accuracy (mean = 4.80), learning objective relevance (mean = 4.75), and task clarity (mean = 4.70).

Table 3. Evaluation Results (Validation) of Learning Tools Based on Media Components

Assessment aspects	Validator (mean score)			Total mean	Criteria
	I	II	III		
Visual/graphical display	4.83	4.83	4.67	4.78	Valid
Software engineering	4.67	4.75	4.67	4.70	Valid
Total mean score of the media aspect				4.74	valid

Meanwhile, Table 3 shows that the media validation component received a slightly higher overall mean score of 4.74, particularly excelling in interactivity (4.83), visual layout (4.78), and language suitability (4.65). These results justify the use of the materials in a real classroom setting.

In the classroom implementation phase, the learning intervention was applied to 62 students in chemistry education using a pre-test and post-test design to assess the impact of the developed model on students' Higher Order Thinking Skills (HOTS). The pre-test was administered before the learning session using a 40-item HOTS-based test, categorized into the C4 (analysis), C5 (evaluation), and C6 (creation) levels of Bloom's taxonomy. The post-test was administered at the end of the instructional cycle, using equivalent test items.

Table 4. Students' HOTS Ability Achievement

HOTS	N	Minimum	Maximum	Mean	Std. Deviation	K-S Test	Sig.
Pre-test	62	23	45	35.71	6.364	0.980	0.293
Post-test	62	65	98	76.94	6.613	1.160	0.135

Table 4 shows that the average HOTS pre-test score was 35.71 with a standard deviation (SD) of 6.36, indicating generally low levels of initial higher-order cognitive ability. After the intervention, the post-test score average increased to 76.94 with an SD of 6.61, representing a substantial learning gain.

To determine the statistical significance of this improvement, a paired-sample t-test was conducted using SPSS version 22.

Table 5. Results of the Effectiveness Test of Teaching Materials

	Paired Differences		t	Sig.	t-tabel
	Mean	Std. Deviation			
Posttest-Pretest	41.226	9.331	34.790	0.000	1.670

The analysis showed (Table 5) a mean gain of 41.226 points in HOTS scores. The t-value was 34.790, and the significance level (p-value) was 0.000, indicating that the improvement was statistically significant ($p < 0.05$). Prior to the t-test, data normality was verified using the Kolmogorov–Smirnov test, which indicated normality and thus met the assumptions for parametric analysis. These results confirm that the Canva-IBL-STEM learning model effectively enhances students' HOTS.

Beyond the quantitative analysis, qualitative observations indicated strong student engagement throughout the learning sessions. Students responded positively to the guided-inquiry structure supported by interactive Canva content. They reported that the visual representations helped them understand stoichiometric concepts such as mole ratios and limiting reagents more clearly. Lecturers noted that students demonstrated improved questioning skills and deeper analysis in class discussions. These reflections affirm that visual scaffolding combined with inquiry-based exploration facilitates deeper learning, as previously supported by Catubig et al. (2024).

The novelty of this study lies in integrating Canva not only as a design or display tool but also as a structured, inquiry-embedded learning environment. This contrasts with earlier research, where Canva was mainly used for visual products or poster design. In this study, Canva was embedded within the IBL-STEM cycle, from initial question formulation, data exploration, synthesis, and evaluation, leading students to create meaning from chemical data.

Furthermore, the STEM integration allowed students to apply concepts beyond the classroom. For example, problems involving reaction efficiency and environmental impact provided them with contexts that required mathematical reasoning, scientific understanding, and evaluative thinking. These tasks supported HOTS at multiple levels, helping students not only to learn chemistry but to relate it to real-life problem-solving. This is consistent with the findings of Antonio & Prudente (2024), who highlighted the potential of STEM-driven inquiry to enhance critical thinking and creativity.

In summary, the Canva-IBL-STEM model demonstrated strong validity and effectiveness for promoting higher-order thinking skills in stoichiometry learning. The combination of statistically significant cognitive improvement, expert validation, and positive student response supports the model's practical implementation in chemistry education. It fills a methodological gap by integrating digital visual design into structured inquiry and STEM learning, setting a foundation for future innovation in science pedagogy.

CONCLUSION

This research has demonstrated that integrating Canva within an Inquiry-Based Learning and STEM (Canva-IBL-STEM) framework is both pedagogically valid and empirically effective in enhancing students' Higher Order Thinking Skills (HOTS) in stoichiometry learning. Through a structured development process guided by the ADDIE model, the resulting learning modules achieved a high level of content and media feasibility, as validated by experts. Classroom implementation confirmed a significant increase in students' HOTS performance, as indicated by pre- and post-test comparisons and reinforced by positive student engagement and qualitative observations. The novelty of this model lies in using Canva not only as a visual design tool but also as an integrated pedagogical medium that scaffolds inquiry-based activities and contextual STEM challenges. By embedding visual, interactive, and problem-solving elements into the learning process, the model offers a more engaging and cognitively rich alternative to conventional chemistry instruction. This integration supports conceptual clarity, reduces cognitive load, and promotes deeper reasoning, thereby aligning well with the cognitive demands of 21st-century science education. This study also contributes to the growing body of evidence supporting technology-based learning and digital visualization as transformative elements in science pedagogy. This study also suggests the need for large-scale implementation and testing, as well as the development of Canva-IBL-STEM-based learning materials on chemistry topics for different educational levels. This study thus encourages educators and curriculum developers to explore creative, technology-enhanced approaches that support not only content mastery but also the development of critical, evaluative, and creative thinking skills essential for future scientific literacy.

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