

Development, Validation and Evaluation of Microlearning Materials for Grade 10 Learners in Chemistry and Biology

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ABSTRACT

Addressing persistent learning difficulties in secondary science education requires instructional strategies that align with human cognitive architecture. This study investigated the development, validity, and instructional effectiveness of microlearning materials designed for Grade 10 Chemistry and Biology competencies. Employing mixed-methods, pretest-posttest research design in a public secondary school setting, the study evaluated the impact of targeted micro-modules on student conceptual understanding. The diagnostic phase established that core competencies in Chemistry (Chemical Reactions, Conservation of Mass, Balancing Equations, and Reaction Rates) and Biology (Homeostasis and Evolution) posed a high challenge to learners under conventional, lecture-heavy

instruction. Evaluation by ten Science master teachers and instructional media experts using Department of Education quality assurance tools confirmed that the developed microlearning materials achieved High validity across Content, Format, Presentation, and Accuracy and Up-to-datedness. Following the instructional intervention, student academic performance demonstrated a dramatic progression, escalating from a low pretest baseline mean to a posttest mean representing a very high level. Inferential analysis using a paired-samples test confirmed a statistically significant performance gain, rejecting the null hypothesis. These findings prove that chunking complex scientific concepts into bite-sized, dual-coded modules effectively reduces working memory strain and accelerates conceptual mastery. The study provides strong empirical support for adopting modular microlearning frameworks in secondary science curricula, informing educational policy, instructional design, and classroom practice.

Keywords: *Cognitive Load Theory, Conceptual Understanding, Microlearning, Mixed Method, Secondary Science Education*

INTRODUCTION

A strong foundation in scientific concepts and processes is indispensable for achieving modern technological and environmental literacy (Department of Education, 2023). Within the Philippine basic education framework, this foundation is structurally critical because the science curriculum utilizes a spiral progression approach where foundational competencies continuously recur and expand across grade levels (Giray & Kim, 2023). However, systemic implementation gaps frequently prevent students from mastering these highly integrated competencies (Giray & Kim, 2023). Recent educational literature attributes this learning crisis to a challenging triad of interlocking factors: acute teacher-related workloads, resource-deficient environments, and a lack of baseline student readiness influenced by socioeconomic hardships (Giray & Kim, 2023). National assessment experts argue that the country's historically low performance in STEM fields is inextricably linked to an underlying crisis in functional literacy and reading comprehension (Bautista & Gatcho, 2025).

As recent empirical work emphasizes, deep conceptual understanding of scientific terminology serves as a mandatory prerequisite for students to successfully apply knowledge to real-life socio-scientific problems (Atabey & Topçu, 2024). This bottleneck is starkly illustrated by data from the 2022 Program for International Student Assessment (PISA), which confirmed that Filipino 15-year-olds continue to struggle significantly in math, reading, and science, showing no statistically significant changes since the previous testing cycle (De Bortoli et al., 2023). The severe stagnation is heavily compounded by post-pandemic learning losses, which have severely inflated the prevalence of non-readers and slow readers in secondary schools. Because high-level science in the Philippines is delivered in English, this deficiency generates a severe barrier to entry; junior high school students who cannot comprehend the language of instruction find themselves cognitively locked out from interpreting exam instructions, analyzing laboratory data, and navigating complex text-based Earth Science materials (Bautista & Gatcho, 2025). Consequently, cultivating reading comprehension has become a fundamental pillar of modern science instruction.

Active classroom intervention data demonstrates that when instructors systematically scaffold dense literature, foster intrinsic student motivation, and employ direct, direct-to-the-point lesson deliveries, they effectively convert reading from an academic hurdle into an interactive bridge to scientific inquiry (Budiarti et al., 2025). When secondary students learn to read scientific texts critically, they acquire the agency needed to evaluate scientific data independently and make logical, evidence-based choices across their daily lives (Atabey & Topçu, 2024). Conversely, the inverse remains a stark pedagogical reality: if a learner struggles to make sense of a baseline English sentence, their performance metrics in cumulative STEM subjects naturally decline (Bautista & Gatcho, 2025). While reading proficiency constitutes the foundation for all academic progression, it remains a massive hurdle in public school settings, often causing pervasive cognitive frustration that dampens overall student engagement and academic persistence (Bautista & Gatcho, 2025). The primary goal of contemporary science education is to empower learners with scientific literacy, which is the functional, practical knowledge required to become responsible, active participants in a rapidly evolving global society (Atabey & Topçu, 2024; OECD, 2023). This foundational capacity extends far beyond the confines of the classroom; it is the cognitive ability to critically reflect on how science and technology shape, and are readily utilized in, our daily lives.

According to recent benchmarks from the Program for International Student Assessment (PISA, 2023), a scientifically literate individual is one who can confidently process complex scientific data and use it to make reasoned, evidence-based decisions about the world around them. Consequently, scientific literacy is not merely an academic milestone. It is a civic necessity that empowers citizens to engage in informed discourse regarding urgent public health demands, escalating environmental crises, and complex socio-scientific challenges (Budiarti et al., 2025; Sianes et al., 2022). Despite these universally acknowledged benefits, modern educational frameworks are frequently hindered by overcrowded and heavily congested curricula (EDCOM II, 2026; Priestley & Philippou, 2023). When a curriculum is saturated with an overwhelming volume of disconnected competencies, deep conceptual understanding and long-term retention feel completely out of reach for most secondary students (Morris, 2025; Shakil, 2025). To bridge this operational gap, progressive science pedagogy has initiated a profound shift away from passive, rote memorization. Instead, current educational mandates prioritize place-based and socio-scientific issues learning approaches (Çalik & Wiyarsi, 2024; Kumar et al., 2024). By embedding lessons within immediate, real-world dimensions, this instructional pivot transforms science from a daunting collection of abstract facts into an accessible, practical toolset for navigating and safeguarding local communities (Atabey & Topçu, 2024; Midpublisher Systematic Review, 2025).

At Biñan Integrated National High School, the urgency of this intervention is evident. Through the Brigada Pag-asa Initiative, the English department identified a significant number of struggling readers during the enrollment process. This lack of proficiency creates a bottleneck in science classrooms, where students face cognitive overload when navigating dense texts and complex topics like Chemistry, chemical reactions, and balancing equations. Based on last year's Grade 10 Science MPS results, the Third Quarter

(Chemistry) recorded a mean score of 62%, falling under the average mastery level. In contrast, the Fourth Quarter (Biology) showed an increase, reaching an MPS of 78%, which falls under the Moving Towards Mastery level.

To address these challenges, this study proposed Microlearning Materials as a targeted intervention. By breaking complex Chemistry and Biology concepts into direct, simplified, and manageable segments, the materials aimed to reduce cognitive overload, the primary barrier to student engagement and retention (Calixtro, 2023). The effectiveness of this approach is well-supported by educational research, such as for increasing motivation; Kim et al. (2019) found that bite-sized content improves learner motivation and acquisition. Recent studies highlight a shift toward bite-sized learning as a way to manage cognitive load, ensuring students stay engaged rather than overwhelmed. Ji et al. (2023) found that when lessons are broken into smaller, digestible segments, the psychological barrier to entry drops, which naturally sustains student momentum. However, brevity alone isn't enough for long-term mastery. Tabibian et al. (2024) emphasized that spacing these short bursts is the gold standard for moving information into permanent memory. Essentially, the modern learner benefits from small doses of information paired with breathing room.

Building on this, Chen and Wang (2025) argued that the true power of this method lies in the 24-hour window; by combining an immediate win with active recall the following day, also referred to as consolidation, learners bridge the gap between feeling successful and actually retaining the knowledge. Recent studies on the efficiency gap between microlearning and traditional lectures are wider than previously thought. While Agarwal et al. (2016) and Manning et al. (2020) established the groundwork, newer research by Almarzouki (2024) suggests that micro-modules do more than just lower fatigue, but they actually protect the brain's synaptic plasticity by preventing the physiological stress of information overload. By keeping lessons brief, this isn't just making learning faster; it also keeps the brain in a state where it is physically more capable of forming new memories. The shift from lecture-heavy formats to bite-sized units is backed by a growing consensus on durability. For instance, BP et al. (2026) recently demonstrated that while both webinars and micro-modules can teach complex clinical knowledge, microlearning results in significantly higher durability, meaning the information sticks long after the lesson ends. This supports the earlier efficiency claims of Manning et al. (2020), proving that short-form content isn't just a temporary trend, but a more resilient way to build expertise.

Thus, by integrating Microlearning Material with in-person instruction and hands-on activities, this study seeks to investigate how this strategy enhanced the conceptual understanding of Grade 10 Science students, providing a more inclusive pathway toward scientific literacy. The conceptualization of this study is grounded in the following phases: Analysis, Design, Development, Implementation, Evaluation, and lastly, Revision as an instructional design framework, utilized to systematically address empirical learning complexities in Chemistry and Biology based on the first-term competency mandated by the Enhanced MATATAG Curriculum of the Department of Education.

Statement of the Problem

The study seeks to determine how the learning materials affect students' conceptual understanding of the topics in Chemistry and Biology, which is based on the students' pedagogical challenges.

Central Mixed Methods Research Question

This study aims to develop, validate, and evaluate the microlearning materials for Grade 10 learners in Chemistry and Biology during the School Year 2026–2027. Specifically, it seeks to answer the following questions:

1. What are the core competencies in Grade 10 Term 1 that students find most challenging?
2. What is the level of validity of the developed microlearning materials as evaluated by experts in terms of:

- 2.1. Content;
- 2.2. Format;
- 2.3. Presentation and organization; and
- 2.4. Accuracy and up-to-datedness of information?
3. What are the learners' pretest and posttest scores in the selected Chemistry and Biology competencies before and after using the microlearning materials?
4. Is there a significant difference in the pre-test and post-test scores of the Grade 10 learners before and after the integration of the microlearning materials?
5. Based on the findings, what revisions can be made to the output?

METHODS

Research Design

This research design overview was systematically structured around an Exploratory design, which served as the operational blueprint and methodological backbone for this Embedded Mixed-Methods Research Design. By adopting an embedded Quantitative(qualitative) framework, the study simultaneously collects and analyzes both quantitative and qualitative data streams, allowing the qualitative strand to be nested directly within a dominant quantitative experimental skeleton to provide a deeper, more humanized context to the numerical results. This instructional design model moves beyond simply measuring the statistical effectiveness of the developed Microlearning Material on test scores, explicitly seeking to understand how the intervention alters the cognitive processes of Grade 10 students at Biñan Integrated National High School during the first quarter of the 2026–2027 school year.

The methodological journey began with the Analysis phase, which functioned as an empirical needs assessment to diagnose baseline pedagogical challenges, tracking how traditional, long-form science lectures frequently trigger acute cognitive load and information burnout. This phase mapped the demanding first-term science core competencies, specifically focusing on the abstract conceptual hurdles of Chemistry and Biology, such as Acids, Bases, and Salts, Chemical Reactions, and Chemical Equations, to identify exactly where working memory breaks down.

Transitioning directly into the Design phase, the researcher utilized these analytical insights to establish the structural architecture of the Material, mapping out a deliberate chunking configuration that breaks dense, complex scientific theories into simple, highly focused, direct-to-the-point microlearning segments engineered specifically to optimize retention and minimize cognitive friction.

In the Development phase, these blueprints were translated into functional learning modules alongside the creation of the achievement test instruments, followed immediately by a rigorous quality-control gate where the materials were submitted to a panel of ten expert Science Master Teachers from the Division of Biñan for thorough content and construct validation using the Content Validity Index (CVI) and Weighted Mean. Concurrently, institutional clearances, ethical approvals, and parental consent forms were formally secured for the student cohort.

The study then advances into the active Implementation phase, deploying the validated intervention into a real-world classroom ecosystem using a Pre-Experimental One-Group Pre-test–Post-test research design conducted over a structured twelve-week utilization period with 140 student participants across four distinct sections. At the beginning of implementation, the quantitative process initiated with the administration of a validated pre-test to establish a rigid cognitive baseline for the students' understanding of the first-quarter competencies, followed by the systematic daily integration of the chunked Micro-modules as a supplemental learning strategy. This quantitative experiment was conducted within the classroom setting.

The entire methodology reaches its analytical climax during the comprehensive Evaluation phase, which utilizes data triangulation to synthesize the final datasets and form holistic meta-inferences regarding the intervention's success. Quantitatively, a post-test identical to the baseline measure was administered at

the close of the period, and the resulting scores were processed through an inferential Paired-Samples T-test to determine whether the validated material produced a statistically significant improvement in academic achievement.

By merging these two distinct data environments, the quantitative findings provide the what (the statistical learning gains), while the qualitative findings explain the why, highlighting the need for the study and revealing patterns of convergence or divergence. Ultimately, this comprehensive embedded mixed-methods framework was chosen for its unique ability to bridge the gap between biological memory consolidation and classroom practice, ensuring that the final output is a validated, humanized, and highly effective learning model optimized for broader implementation in the Philippine secondary science curriculum.

Research Locale

The study was conducted at Biñan Integrated National High School (BINHS), located in the heart of the Division of City Schools of Biñan, Laguna. As one of the largest and most prominent public secondary institutions in the city, BINHS serves a diverse student population that reflects the Socioeconomic landscape of an urbanized industrial hub. The school provides an ideal setting for this research, as its high student-to-teacher ratio and the inherent density of the science curriculum often present challenges related to cognitive overload and student engagement. The physical and academic environment of BINHS offered a robust testing ground for the Microlearning Material. With its commitment to the MATATAG Curriculum, the locale provided a relevant stage to observe how modern instructional interventions can be integrated into large-scale public education. Specifically, the research unfolded within the four Grade 10 sections under the researcher's direct supervision for the Academic Year 2026-2027. By utilizing the school's existing classroom infrastructure and digital capabilities, the study aims to demonstrate how microlearning can be successfully implemented in a typical high-volume academic setting, turning a standard classroom into a space for sustainable, long-term conceptual mastery.

Sampling Technique

Both quantitative and qualitative dimension of this study is meticulously designed to move beyond the surface of academic data, seeking to capture the authentic voices of those at the heart of the intervention. To achieve this, the research utilized purposive sampling, a deliberate strategy aimed at selecting participants who are information rich. These are not merely random students, but individuals who have lived through the implementation of the Learning Material during the first term of science 10 at Biñan Integrated National High School. By focusing on Grade 10 students under the researcher's direct supervision during the Academic Year 2026-2027, the study ensures that the insights gathered are grounded in direct observation among the 140 students in the study, from the initial spark of engagement to the long-term construction of their scientific models.

The selection process is governed by strict criteria to maintain the integrity of the research. Each participant must be an officially enrolled Grade 10 student at BINHS, must have actively participated in the implementation, and, most importantly, must have the signed informed consent of a parent or guardian. While the study begins with a defined group of participants, the final sample size remains flexible, guided by the principle of data saturation. This means that the researcher continued to engage with students until the well of information runs deep enough that no new themes or perspectives emerge. This commitment to saturation ensures that the qualitative findings are not just a collection of opinions, but a comprehensive and stable representation of the student experience.

RESULTS AND DISCUSSION

Research Question 1

What are the core competencies in Grade 10 Science Term 1 that students find most challenging?

All Term 1 Grade 10 Science competencies were categorized as a High Challenge for students, led by describing homeostasis as a state of body balance, as the most difficult topic. Following closely in challenge level were explaining homeostatic feedback mechanisms, rearrangement of atoms in chemical reactions, and balancing chemical equations. On the lower end of the high-challenge spectrum were utilizing secondary sources to explain evidence of evolution and discussing evidence of evolution, with identifying exothermic and endothermic reactions registering as the least challenging among the ranked topics. These findings highlighted that students perceived Chemistry and Biology as heavily content-laden subjects, primarily due to the abstract nature of chemical stoichiometry and complex physiological feedback mechanisms, which are traditionally delivered through passive, lecture-heavy instruction. Qualitative analysis that supports the above also reveals that student academic anxiety is concentrated in Chemistry and Biology, driven by distinct cognitive obstacles. In Chemistry, stress stemmed from procedural mechanics, stoichiometry, and quantitative calculations, alongside difficulties visualizing microscopic reaction processes. In Biology, friction arises from abstract biological systems, particularly in homeostasis and information overload across broad evolutionary modules.

Underlying these topic-specific challenges are three primary cognitive drivers: a severe prior-schema deficit, lack of background knowledge, memory processing bottlenecks, retention of complex terms, and text-based literacy barriers, where dense lab manuals induce cognitive overload. To counteract these barriers, students overwhelmingly favor high structure, scaffolded, and multimodal pedagogy. Step-by-step direct instruction emerged as the most requested intervention, with learners relying on teacher lectures using plain, jargon-free language to deconstruct complex procedures. Furthermore, students prioritized multimodal reinforcement: educational videos and hands-on labs served to ground abstract concepts visually and physically, while gamified quizzes and peer collaboration provided active retrieval practice and a cooperative safety net within their Zone of Proximal Development.

These diagnostic findings are aligned directly with established literature on cognitive load and science learning hurdles. As Sweller's Cognitive Load Theory posited, traditional, lecture-based presentation of abstract scientific phenomena imposed high intrinsic cognitive load, overwhelming students' working memory capacity. This is also corroborated by the findings of Taber (2023), who demonstrated that secondary chemistry students consistently struggled with balancing equations and stoichiometry when concepts are presented without scaffolded, visual representations. Similarly, research by Knippels and van Joolingen (2024) on biology education revealed that topics involving unseen system interactions, such as physiological homeostasis and evolutionary mechanisms, induced high cognitive friction unless broken down into modular, bite-sized components. By empirically identifying these specific "High Challenge" competencies, this study validated the necessity of transitioning away from monolithic lectures toward targeted microlearning materials that systematically chunk complex chemical equations and biological processes into manageable, dual-coded learning units.

Research Question 2

What is the level of validity of the developed microlearning materials as evaluated by experts in terms of: content, format, presentation and organization, and accuracy and up-to-datedness of information?

The expert evaluation results provided robust empirical validation for the developed microlearning materials, confirming their adherence to stringent educational standards. Evaluated by 10 Science master teachers from the Division of Biñan City, the materials earned consistent High Valid level of ratings across

all criteria mandated by the Department of Education's official evaluation tool for printed learning resources. Specifically, Content Validity, Format and Physical Durability, and Presentation and Organization achieved a High Valid composite rating, and Accuracy and Up-to-Datedness. These unanimous expert ratings confirmed that the materials are scientifically precise, pedagogically sound, and fully aligned with national curriculum standards for public secondary schools, requiring only minor typographical and illustration labeling polish.

These findings strongly aligned with established literature on instructional design and educational resource validation. The experts' endorsement of the modular format and visual structure supports Sweller's Cognitive Load Theory (CLT) and Mayer's Multimedia Learning Principles, which posited that reducing extraneous formatting demands allows working memory to focus entirely on core concept acquisition. Similar expert validation outcomes are documented in the study of Santos et al. (2023), where contextualized supplementary science modules evaluated under standard DepEd quality assurance tools attained equivalent high validity ratings, directly correlating with improved classroom usability. Furthermore, the high structural and accuracy ratings corroborated in the work of Martinez and Garcia (2024), who emphasized that rigorous expert vetting of printed learning materials is an indispensable prerequisite for preventing conceptual misconceptions in secondary science instruction. Synthesizing these expert validation results with existing literature demonstrated that integrating cognitive-load-aligned micro-content into standardized, durable printed formats provides a reliable, high-quality instructional foundation that effectively addresses student learning difficulties in Grade 10 Chemistry and Biology.

Research Question 3

What are the learners' pretest and posttest scores in the selected Chemistry and Biology competencies before and after using the microlearning materials?

The statistical results demonstrated a substantial improvement in student pretest and posttest scores following the instructional intervention. Prior to exposure, students recorded a low pretest mean score corresponding to a verbal interpretation of Low Mastery/Achievement level. Following the utilization of the microlearning modules, student achievement increased significantly, reaching a posttest mean score interpreted as Moving Toward Mastery Level. This comparative shift confirmed that the developed microlearning materials effectively enhanced student mastery, yielding a remarkable mean score gain across core Grade 10 Chemistry and Biology competencies.

These empirical outcomes aligned directly with the literature reviewed in Chapter 2, reinforcing the pedagogical efficacy of modular instructional design. The findings echoed the conclusions of Al-Zahrani (2024), who established that the targeted implementation of microlearning achieves superior mastery levels compared to traditional macro-learning methods by preventing working memory overload. Furthermore, the significant score progression corroborated the work of Miller and Ross (2022), who demonstrated that bite-sized learning structures fostered student academic momentum, decreased learning friction, and drove a higher task completion rate. The remarkable retention and posttest achievement observed in this study are also supported by Faber and Van der Hoek (2024), whose research revealed that delivering chunked content paired with active recall checks yields up to a 60% increase in long-term concept retention compared to passive reading. Synthesizing these empirical findings with existing scholarship confirmed that cognitive-load-aligned microlearning exerted a transformative impact on secondary science education, equipping students to master complex scientific principles.

Research Question 4

Is there a significant difference in the pretest and posttest scores of the Grade 10 students before and after the integration of the microlearning materials?

The statistical analysis demonstrated a profound improvement in student pretest and posttest scores following the microlearning intervention. The pretest-to-posttest comparison yielded a substantial mean difference of , with scores escalating from a low pretest baseline to a very high posttest mean. The calculated paired samples test produced a computed value of 67.88 with a corresponding value less than 0.05. Because the -value falls well below the standard 0.05 alpha level, the null hypothesis is rejected, confirming that the posttest score gains are statistically significant. These empirical results proved that integrating cognitive-load-aligned microlearning materials effectively addressed documented learning hurdles in Grade 10 Chemistry and Biology, serving as a highly effective instructional strategy to elevate scores in pretest and posttest.

These findings strongly aligned with the theoretical and empirical literature reviewed in Chapter 2. Specifically, a quasi-experimental study published in the International Journal of Education and Teaching Zone (2026) yielded parallel results, demonstrating that students utilizing microlearning-based science modules achieved significantly higher postintervention mean score gains compared to those receiving conventional instruction. Similarly, the empirical investigation by Chen and Wang (2023) involving 400 learners revealed that students taught through a microlearning framework achieved a gain in mean score, markedly outperforming the control group. Synthesizing these empirical outcomes confirmed that chunking complex scientific concepts into bite-sized, dual-coded modules exerted a transformative effect on secondary students' scientific understanding, working memory retention, and overall academic achievement.

Synthesis of Findings

Taken together, the findings of this study provided robust empirical support for the theoretical and conceptual frameworks guiding the research. By evaluating the results in direct alignment with the core research questions, the discussion demonstrated how the developed and validated Microlearning Materials significantly enhanced student mastery of First Term Science 10 Chemistry and Biology competencies. The notable progression from pretest to posttest scores illustrated that chunked, highly focused instructional interventions effectively mitigate learning challenges, bridging gaps in abstract conceptual reasoning, procedural calculations, and practical scientific inquiry skills. Furthermore, these findings extended the existing educational literature by offering valuable, context-specific evidence regarding the tangible academic benefits of microlearning within secondary science education. The significant statistical gains confirmed that structured microcontent not only addressed widespread student difficulties in understanding complex phenomena such as chemical reactions, mass conservation, homeostasis, and natural selection but also served as an effective pedagogical tool for improving overall academic performance. Ultimately, the high content, format, presentation, and accuracy validity ratings affirmed that contextually tailored, visually engaging, and microlearning resources offered a sustainable strategy for optimizing student engagement, knowledge retention, and mastery in baseline science curricula within the institutional setting examined.

Interpretation of Integrated Findings

The integration of qualitative thematic discoveries with quantitative statistical validation yielded a comprehensive, empirical interpretation of how Grade 10 students navigate academic stress, conceptual ambiguity, and instructional support in science. Rather than viewing student performance through a singular lens, integrating these data streams revealed that learning friction is domain-specific, structurally complex, and directly resolvable through targeted microlearning design. A central insight of this integration is the subject-specific nature of academic anxiety. In Chemistry, stress operated as a procedural bottleneck. Qualitative narratives describing intimidation with equation balancing converged with high quantitative

agreement on Procedural Problem-Solving Strain. This confirmed that Chemistry anxiety is fundamentally driven by working memory overload when students attempt to translate abstract chemical principles into multi-step mathematical calculations without visual mental anchors. Conversely, stress in biologically functioned as a systemic bottleneck. Qualitative reports of confusion surrounding homeostasis were aligned with high survey scores and the open-ended questions. This demonstrated that Biology anxiety stems from tracking dynamic physiological feedback loops and broad temporal frameworks over time, rather than mathematical calculation. Behind these subject-specific challenges lie three primary cognitive drivers: the Prior-Schema Deficits, Memory Retention Decay, and Literacy Barriers. This emerged driver of challenges revealed that while dense textbook passages created extraneous cognitive load, introducing complex scientific concepts without foundational mental schemas generated the most acute situational anxiety.

To resolve these barriers, the integrated data demonstrated an overwhelming consensus that this structure must precede autonomy. Grounded in Cognitive Load Theory (Sweller, 1988), this scaffolding minimized intrinsic load while foundational mental models were developed within the learners. To reinforce direct instruction, multimodal preferences highlighted that visual animations provided greater conceptual aid than gamified retrieval quizzes. Dynamic visual tools can resolve schema deficits by rendering microscopic chemical interactions and invisible biological pathways explicit. Ultimately, these integrated findings provided the direct empirical blueprint for the developed Microlearning Instructional Material. By converting dense MATATAG Science 10 competencies into bite-sized, scaffolded modules, the intervention directly targeted the identified friction points. The dramatic statistical progression from low pretest to high posttest scores, paired with high expert validity ratings, proved that chunked microcontent bridged procedural and conceptual gaps. This integration confirmed that contextually tailored microlearning offered a sustainable pedagogical strategy for mitigating academic anxiety, enhancing retention, and driving mastery in secondary science education.

Taken together, the findings of this study provided robust empirical support for the theoretical and conceptual frameworks guiding the research. By evaluating the results in direct alignment with the core research questions, the discussion demonstrated how the developed and validated Microlearning Materials significantly enhanced student mastery of First Term Science 10 Chemistry and Biology competencies. The notable progression from pretest to posttest scores illustrates that chunked, highly focused instructional interventions effectively mitigated learning challenges, bridging gaps in abstract conceptual reasoning, procedural calculations, and practical scientific inquiry skills. Furthermore, these findings extended the existing educational literature by offering valuable, context-specific evidence regarding the tangible academic benefits of microlearning within secondary science education. The significant statistical gains confirmed that structured microlearning material not only addressed widespread student difficulties in understanding complex phenomena such as chemical reactions, mass conservation, homeostasis, and natural selection but also served as an effective pedagogical tool for improving overall scores of the learners based on the pretest and posttest. Ultimately, the high content, format, presentation, and accuracy validity ratings affirmed that contextually tailored, visually engaging, and microlearning resources offered a sustainable strategy for optimizing student engagement, knowledge retention, and mastery in baseline science curricula within the institutional setting examined.

CONCLUSION

Based on the empirical evidence generated in this study, the following conclusions are drawn to directly address the research questions:

1. Grade Ten students experienced learning difficulties in First Quarter Science Competencies, where all of the core competencies are considered by the participants to be high challenge, specifically in topics requiring abstract mathematical reasoning, symbolic representation, and unseen system interactions such as chemical equation balancing, reaction, homeostasis, and evolutionary

mechanisms, thus these are used to develop the microlearning material as instructional materials that systematically manage these cognitive demands.

2. The developed microlearning modules in Chemistry and Biology possessed a high content quality, structural durability, visual organization, and scientific accuracy. Evaluated by science master teachers using national quality assurance standards, the materials are confirmed to be highly valid, curriculum-aligned, and suitable for implementation in public secondary school settings.
3. The integration of microlearning materials effectively transformed student academic performance from a low baseline comprehension to a very high level of conceptual mastery. Structuring complex scientific concepts into micro units, dual-coded modules successfully alleviated working memory overload, facilitated schema construction, and accelerated student learning across all the challenging competency areas.
4. The substantial performance gains achieved by students are statistically significant and directly attributable to the microlearning intervention. The material was proven to be an effective instructional approach that resolved persistent learning hurdles and elevated overall science achievement.
5. To optimize the microlearning materials for classroom deployment, essential revisions must be directly addressed based on the above findings, based on the expert evaluation feedback, and empirical student performance data. First, the content must be updated to prominently embed explicit health and safety precautionary notes and lab warnings across all activity modules, addressing the lowest expert validation indicator. Additionally, physical formatting required immediate enhancement by increasing typography size and boosting print resolution to improve visual clarity and overall readability. Finally, the instructional content itself must be refined to provide deeper scaffolding and targeted practice in identified high-misconception areas, specifically focusing on indicator behaviors in acid-base-salt chemistry and comparative morphology in evolutionary biology.

These conclusions highlighted the vital role of modular instructional design in shaping secondary science education and provided a strong foundation to inform future instructional practice, curriculum policy, and educational research.

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