

A Gamified Strategic Intervention Material Competency-Based Instruction (SIM CBI) to Enhance the Academic Performance of Learners in Earth and Life Science

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Index Terms:

gamified learning, strategic intervention material, competency-based instruction, scientific literacy

Abstract. Persistent low performance in Science among Filipino learners, as evidenced by international assessments such as PISA and TIMSS, highlights a critical gap in the development of scientific literacy, particularly in understanding complex concepts in Earth and Life Science. This issue is further heightened by limited use of engaging, differentiated, and competency-based instructional materials that address least mastered skills. To address this gap, this action research investigated the effectiveness of a Gamified Strategic Intervention Material using a Competency-Based Instruction (SIM CBI) approach in improving the academic performance of Grade 11 learners. Anchored in Differentiated Instruction, Game-Based Learning, and Constructivist Learning theories, the study utilized a mixed methods design in which meta-synthesis and meta-analysis intersection was analyzed to elicit its meta-inference relationship. A meta-analysis procedure (pre-test and post-test) identified least mastered competencies, followed by the implementation of gamified intervention materials tailored to these learning needs. Results showed a significant improvement in learners' performance, with mean scores increasing from 4.286 to 8.571, supported by a statistically significant p-value (<0.001). Meta-synthesis (qualitative findings) revealed that learners found the material engaging, clear, and helpful in understanding concepts through visual aids and interactive elements. Overall, the study meta-inference demonstrates that gamified, competency-based intervention materials effectively address learning gaps and enhance academic performance, scientific literacy, and learner engagement in science. Different teaching and learning theories were supported in developing learners' problem-solving confidence, and problem-solving capabilities. The Gamified Strategic Intervention Material is both statistically effective in improving scientific literacy and pedagogically sound in its design, as perceived by students. Its success is driven by clear explanations, supportive visual aids, and interactive elements.

Introduction

Based on DepEd Order No. 31, s. 2012 and DepEd Order No. 010, s. 2024, the current MATATAG curriculum, together with its backbone, the K to 12 Program, says that Science Education aims to develop scientific literacy among learners that will prepare them to be participative citizens who can make judgments and decisions regarding the application of their scientific knowledge in providing creative solutions to difficult problems. Thus, learners are expected to solve practical problems in the community that require scientific literacy practices.

Earth and Life Science, one of the Core subjects at the Senior High School (SHS) level, is a science subject designed to provide a general background for understanding Earth Science and Biology (Kto12 Science Curriculum Guide, 2016). This core subject presents different scientific concepts that could help learners critically address community issues requiring analyzing scientific evidence. However, Palines and Cruz (2021) found that scientific literacy among learners in terms of writing was perceived as good while presenting the scientific research was described as fair. Results of international

assessments, like PISA and TIMSS, however, show Filipino learners' poor performance in Science (Mullis et al., 2020; (PISA 2022 Results (Volume I and II) - Country Notes: Philippines, 2023).

Analyzing such factors that hinder the development of scientific literacy among learners is one of the ways to address this poor performance of learners in science. Palines and Cruz (2021) identified several facilitating factors that need improvement and development to enhance learners' scientific literacy. Such factors are (a) the use of differentiated instructions, (b) the development of modules, and (c) the plan of activities. Educators have to provide learners with various learning materials that could help them enhance their scientific literacy practice, and providing strategic intervention material is another option. In the study of Villaran, et al. (2023), they revealed that there was an improvement after the intervention made to learners with learning competencies needed as reflected during the diagnostic tests. The majority of the learners who need the intervention find the strategic intervention material in Science to be effective in improving their academic performance. Thus, providing competency-based strategic intervention material could also help learners develop their scientific literacy practice to learn about concepts in Earth and Life Science.

Research Questions

This action research aims to understand how effective the use of strategic intervention among learners is. Specifically, this aims to answer the following questions:

What least mastered skills are identified based on the results of the Pretest in Earth and Life Science?

What is the learners' scientific performance level in the Earth & Life Science Pretest before utilizing the Gamified Strategic Intervention Competency-Based Instruction?

Is there a significant difference in the respondents' scientific literacy before and after utilizing the Strategic Intervention Competency-Based Instruction?

How effective is the Gamified Strategic Intervention Competency-Based Instruction in content and quality?

Assumptions of the Study

This action research proposes strategic intervention materials on the subject of Earth and Life Science. These strategic intervention materials aim to enhance learners' scientific literacy practice and serve as an "aid" for instructional materials in teaching to facilitate learning and improve the performance of learners (G. Bonitez, A, 2021, Sinco, 2020). This proposed intervention will focus on the competencies of the subject (competency-based) with the least mastered skills.

Methodology

Before the conduct of intervention

The researcher conducted a pre-test among selected learners to elicit their current knowledge about the subject. The results of the pre-test determined the list of competencies with the least mastered skills. Each identified competency was provided with intervention material. This intervention material followed a gamified approach to capture the attention and focus of learners while doing their tasks. The crafted strategic intervention materials has been validated, reviewed, revised, and improved by the school research committee and group of selected science teachers, to ensure the validity of the said materials.

During the conduct of the intervention

Each competency was drilled for a week using the developed and validated strategic intervention material. Every after the intervention session, learners, together with the facilitator had a conference as a form of feedback. This feedback session elicited the teaching and learning experience with the use of strategic intervention material.

After the conduct of the intervention

The researcher assessed the learners using multiple assessment tools to determine if there is an improvement when it comes to learners' scientific literacy practice.

Theoretical And Conceptual Framework

In the pursuit of enhancing learner's engagement and academic performance, particularly in complex scientific topics, researcher has increasingly emphasized the need for responsive, engaging, and student-centered instructional approaches. This study is grounded in three interrelated learning theories, Differentiated Instruction Theory, Game-Based Learning

Theory, and Constructivist Learning Theory which collectively guide the design, implementation, and assessment of gamified and visually enriched Strategic Intervention Materials (SIMs).

Differentiated Instruction Theory, more often as the differentiation approach in education is grounded in the understanding that each student possesses distinct learning needs, interests, and abilities. Recognizing that a uniform teaching method cannot effectively engage all learners, this approach seeks to customize instruction to address the varied needs of students in the classroom (Goyibova et al., 2025). Strategic Intervention Materials inherently reflect this principle, as they are designed to address learning gaps through scaffolded, varied, and accessible content. When embedded with gamified and visual elements, SIMs become not only remedial but also inclusive, dynamic, and motivating.

Game-based Learning Theory or Gamification in Science Education, often referred to as gamified learning, involves incorporating game elements into the learning environment to create a playful and engaging experience for students (Ratinho & Martins, 2023). Originating from game mechanics, this approach has increasingly been explored within schools. When implemented effectively, gamification enhances student motivation and encourages greater participation in academic activities. In this study, game-based elements were integrated into SIMs to transform traditional review materials into interactive learning experiences that reinforce conceptual understanding through play.

Constructivist Learning Theory, grounded in the works of Piaget and Vygotsky, provides the foundational view that learners actively construct knowledge through experience, reflection, and social interaction. The use of visually enriched gamified materials enables learners to form their own understanding through exploration, visualization, and manipulation of content, aligning with this constructivist approach. Moreover, having a constructivist environment helps learners to develop problem-solving confidence, approach-avoidance style, and personal control in constructing their knowledge using gamified learning materials (Tsai et al., 2023). To evaluate the effectiveness of this instructional strategy, a mixed methods design was employed. Quantitative data were analyzed using a paired sample t-test, serving as a meta-analysis to determine whether there was a statistically significant improvement in student performance before and after the implementation of the intervention. Meanwhile, qualitative data gathered from student feedback were subjected to thematic analysis following Braun and Clarke's (2006) six-phase framework. This meta-synthesis yielded themes that illuminated students' perceptions of clarity, engagement, and conceptual understanding.

Finally, a meta-inference was drawn by integrating findings from both strands. The statistically significant gains observed in the quantitative data were reinforced by rich qualitative insights, indicating that the differentiated, gamified, and constructivist design of the SIMs not only improved academic outcomes but also enhanced students' learning experiences. This alignment across data types strengthens the validity of the intervention and supports the use of gamified visual SIMs as a strategic instructional tool.

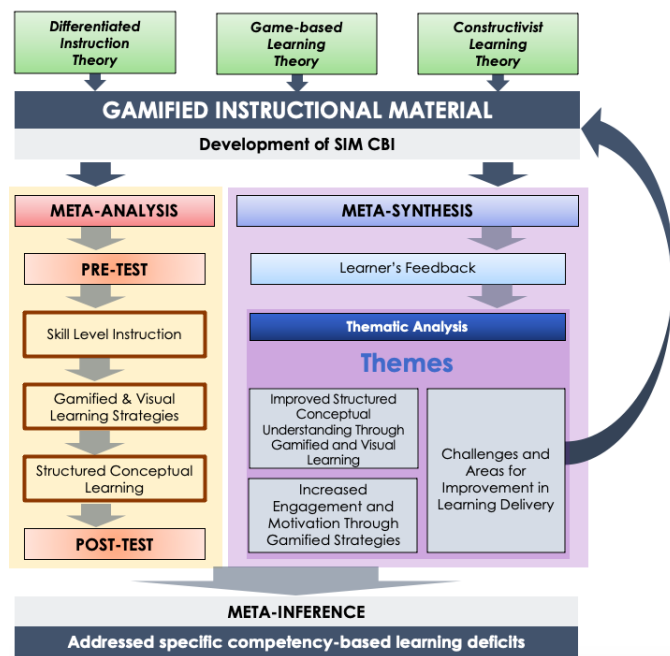


Figure No. 1. Meta-inference on Utilizing Gamified Strategic Intervention Competency-Based Instruction (SIM CBI)

This action research used a Mixed Methods research design. By integrating data from both qualitative and quantitative sources, the researcher will gain valuable insights to answer the research questions.

Participants and/or other Sources of Data and Information

The participants of this action research were Grade 11 learners from TVL-ICT strands. Since this action research is in its trial stage, a purposive sampling method were used to determine the sample participants.

Data Gathering Methods

The researcher sought approval from the Schools Division of the Rizal Office – Sub-Office of Montalban through PRAISE Committee to allow the conduct of the action research. Similarly, the researcher asked the school head’s permission to proceed with the study. The development of gamified strategic intervention material and multiple assessment tools that have provisions for contextualization will be prepared and used as various research instruments. There were pre-test and post-test session of the subject to elicit if there is a significant difference between the two assessments.

Results and Discussion

This study used a Mixed Methods research design that requires qualitative and quantitative data. Thus, the data gathered in this study are in the form of numbers and descriptions. For the pre-test and post-test materials, Statistical Mean was utilized. Meanwhile, for the qualitative data, interview transcripts, and focus group discussion (FGD) were used to gather various insights from the learning experience of the learners.

TEST	Mean	SD	T-computed	P-value	Difference
Pre-test	4.286	0.726	-14.082	<0.001	Significant
Post-test	8.571	0.756			
Difference	4.286				

Condition: If the P-value is lesser than the alpha level ($\alpha = 0.05$) of significance, thus, difference is significant.

Table 1: A Quantitative Meta-analysis of Data Results – Pretest and Post-test

The results of the paired sample t-test revealed a statistically significant improvement in participants' performance from the pre-test to the post-test. The mean pre-test score was 4.286 (SD = 0.726), while the mean post-test score increased to 8.571 (SD = 0.756), yielding a mean difference of 4.286. The computed t-value was -14.082 with a p-value less than 0.001. Given that the p-value is significantly lower than the alpha level of 0.05, the null hypothesis is rejected. This indicates that the difference in scores is statistically significant and not due to random chance. These findings suggest that the intervention applied between the pre- and post-test phases had a substantial and positive effect on learner performance.

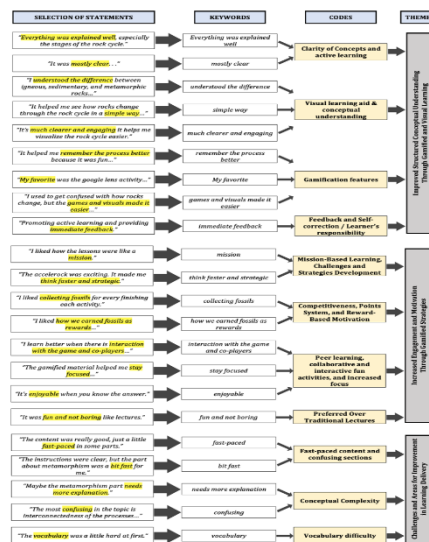


Figure No. 2: An Inductive Thematic Approach of Meta-synthesis Data Results

A thematic meta-synthesis was conducted to analyze learner responses to the question regarding the clarity and comprehensibility of the gamified intervention material. Following Braun and Clarke' (2006), six-phase framework for thematic analysis: familiarization, coding, theme development, theme review, theme definition, and write-up the data were coded line-by-line, generating recurring patterns which were then synthesized into overarching themes.

The initial coding phase revealed frequent references to clear explanations, especially concerning the stages of the rock cycle, and appreciation for the use of simple language and relatable examples. These formed the core of the first theme: Improved Structured Conceptual Understanding through Gamified and Visual Learning. Supporting codes included "easy to follow," "explained well," and "simple words and examples."

The second major theme, Supportive Visual and Structural Elements, emerged from data segments highlighting the effectiveness of diagrams particularly the rock cycle diagram, and structured sequencing of concepts. These visual tools were instrumental in facilitating understanding for many learners.

A third theme, Localized Confusion in Scientific Concepts, emerged through recurring challenges related to scientific terminology (e.g., metamorphism, igneous rocks) and conceptual complexity (e.g., the interconnectedness of rock cycle processes). Though these areas did not dominate the dataset, their recurrence across multiple responses signaled a meaningful point of confusion.

Another salient theme was Pacing and Cognitive Load, where participants indicated that while the material was generally well-developed, some parts felt rushed. Codes under this theme included "fast-paced," "a bit fast," and "needed more explanation."

Finally, the theme Collaborative Mediation and Learner Strategies reflected how peer interaction and self-regulated efforts helped bridge areas of difficulty. Several students indicated that collaborative activities provided needed support for understanding difficult concepts.

In summary, the meta-synthesis of qualitative responses suggested that the gamified instructional material was widely perceived as accessible and effective, especially due to its clarity, visual aids, and interactive components. However, specific improvements are recommended in scaffolding complex topics, pacing certain sections, and supporting vocabulary development, which would further enhance learner comprehension and engagement.

A Mixed-methods Meta-inference of Data Results

Sequential approach: First conduct separate meta-analysis and meta-synthesis, then integrate results.

Convergent approach: Analyze both datasets side-by-side and look for confirmation, contradiction, or expansion between them.

Quantitative finding: Gamified instruction increases test scores by 4.286%.

Qualitative finding: Students feel more motivated and say they learn better through gamification.

Integrated conclusion: Gamified instruction not only improves performance (quantitative) but is also perceived positively by learners (qualitative).

Conclusion and Recommendations

Meta-Inference from the Combined Meta-Synthesis and Meta-Analysis Results:

The integration of both qualitative thematic meta-synthesis and quantitative meta-analysis provided a comprehensive understanding of the effectiveness of the gamified instructional material. The quantitative evidence revealed a statistically significant improvement in student performance from pre-test to post-test, indicating that the intervention had a substantial positive impact on learning outcomes.

This improvement is further explained and contextualized by the qualitative findings, which highlight specific features of the material that contributed to its effectiveness namely, the clarity of explanations, accessibility of language, visual aids, and opportunities for collaborative learning. At the same time, the qualitative data illuminate nuanced challenges such as confusion with scientific terminology, pacing issues, and the need for scaffolding complex concepts.

Therefore, the meta-inference is:

the gamified Strategic Intervention Material is both statistically effective in improving scientific literacy and pedagogically sound in its design, as perceived by students. Its success is driven by clear explanations, supportive visual aids, and

interactive elements. However, to maximize its instructional value, targeted refinements should be made to address specific conceptual challenges and pacing concerns identified qualitatively.

This meta-inference reflects a convergent validation of the intervention's impact where quantitative improvement in scores is substantiated by student-reported experiences, thus enhancing the credibility, relevance, and actionable value of the research findings.

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Competing Interests Statement

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study; all data used were obtained from previously published sources as cited in the reference list.

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Appendices

No appendices are attached to this study.