Impact of Gamified and Mobile Learning on Scientific Inquiry Skills: A Narrative Literature Review

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Abstract: This literature review synthesizes current empirical research to explore the relationship between the use of gamified and mobile learning applications and the development of scientific inquiry skills among senior high school students. The review first establishes that these technologies offer a significant positive advantage over traditional, lecture-based instruction by shifting learning from passive reception to active investigation. It then examines the crucial role of student engagement as a causal mediator, linking the use of technology-enhanced platforms to improved academic performance. Finally, the paper investigates how socio-demographic factors, such as age, academic track, and gender, and, most importantly, access to technology and the internet, act as critical moderators that shape the effectiveness of these educational interventions. Findings from a range of studies and meta-analyses suggest that while gamified and mobile learning are powerful tools, their full potential can only be realized when implemented with careful consideration of these moderating variables.

Keywords: *Gamification, Mobile Learning, Scientific Inquiry, Student Engagement, Academic Performance, Socio-Demographic Factors, Technology Access, Digital Divide, STEM Education.*

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I. INTRODUCTION

Technology, especially gamified and mobile learning applications, is transforming science education by moving beyond traditional, passive lectures to promote active learning and scientific inquiry skills. The National Research Council (2000) defines scientific inquiry as the ability to ask questions, design experiments, and analyze data. These digital tools, as noted by Liu et al. (2021) and Kalogiannakis et al. (2021), provide dynamic environments that simulate real-world scientific processes through virtual labs and game-based challenges, helping students develop crucial skills in a low-stakes setting.

The motivational aspects of gamification, such as points and badges, are welldocumented to boost student engagement and persistence (Hamari et al., 2014; Sailer et al., 2017). This aligns with Self-Determination Theory (Ryan & Deci, 2000), which posits that these features support a student's sense of autonomy, competence, and relatedness. When effectively integrated, these elements can lead to improved academic performance and better retention of scientific concepts, as shown by Husnaini & Chen (2019).

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However, the effectiveness of these technologies is not universal, particularly in the Philippines, where disparities in technology access and digital literacy pose significant challenges to implementation (Estrañero, 2024; So et al., 2020). Sociodemographic factors like age, academic track, and gender also act as moderating variables, influencing how students interact with these tools and affecting learning outcomes (Jia, 2020; Siddiq et al., 2019). For example, older students might be more cognitively prepared for these tasks, and STEM-focused learners may benefit more from simulation-based platforms (Icenogle et al., 2019; Towner, 2023).

This literature review synthesizes research to understand the complex relationship between gamified and mobile learning and the development of scientific inquiry skills. It explores the causal influence of these technologies, the crucial role of engagement as a link to academic performance, and the moderating effects of socio-demographic factors and technology access. By examining these different aspects, the review aims to provide a comprehensive framework for future research and policy in technologyenhanced science education.

II. FRAMEWORK

This study is anchored on a framework where gamified and mobile learning applications serve as the key inputs, together with the learners' and teachers' characteristics, the availability of inquiry-based learning resources, and the conditions of technology access such as device ownership, internet stability, and digital literacy. These inputs are translated into classroom activities through the implementation of gamified mobile inquiry learning, where students engage in inquiry tasks such as asking questions, formulating hypotheses, conducting investigations through simulations or virtual labs, collecting and interpreting data, and drawing evidence-based conclusions, supported by gamification features (e.g., quests, points, badges, progress tracking, and immediate feedback) and teacher facilitation through scaffolding and reflective discussions. As students complete these activities, the expected outputs include completed inquiry modules and learning artifacts (hypotheses, experiment plans, data tables/graphs, and reflections), engagement records, and formative assessment results. The framework assumes that these outputs lead to short-term outcomes such as increased student engagement (behavioral, emotional, and cognitive) and improved inquiry process behaviors, which in turn produce medium-term outcomes reflected in higher scientific inquiry skills performance and better science learning achievement. However, the framework also recognizes that the effectiveness of gamified and mobile learning is not uniform; the strength of its impact on engagement and inquiry skills may vary depending on socio-demographic factors (e.g., age, gender, academic track) and technology access conditions (digital divide). Ultimately, the framework emphasizes that effective and equitable integration of gamified mobile learning can enhance senior high school students' scientific inquiry competence and provide a practical basis for teacher implementation guides and broader school adoption.

III. OBJECTIVES

The objectives of this study are set to clearly describe what shall be done with the data gathered and synthesized from the literature. (1) The study shall analyze the collected findings to determine how gamified and mobile learning applications contribute to the development of scientific inquiry skills among senior high school students, focusing on their ability to ask questions, design experiments, and interpret data. (2) The study shall organize and interpret evidence to explain how student engagement functions as a mediating factor, showing how motivational features such as points, badges, and quests translate into improved academic performance and deeper cognitive processing. (3) The study shall evaluate the data to identify the moderating effects of socio-demographic variables and technology access, thereby clarifying how age, academic track, gender, and the digital divide influence the effectiveness of gamified and mobile learning in science education.

IV. METHODOLOGY

A narrative literature review involves a systematic yet flexible approach to synthesizing existing research on a specific topic. The process begins with the identification of a clear research question or objective, which guides the selection of relevant literature. Researchers typically search academic databases such as Scopus, Web of Science, ERIC, and Google Scholar using carefully chosen keywords and Boolean operators. Unlike systematic reviews, narrative reviews do not require rigid inclusion or exclusion criteria, allowing for a broader exploration of theoretical, empirical, and contextual studies. Once sources are gathered, the researcher critically reads and categorizes them based on themes, methodologies, and findings to construct a coherent narrative that highlights trends, gaps, and contradictions in the literature.

The next phase involves synthesizing the selected studies into a structured narrative. This includes organizing the literature around key themes or concepts, comparing and contrasting findings, and identifying areas of consensus or debate. The researcher interprets the implications of the literature in relation to the research question, often integrating theoretical frameworks to deepen the analysis. Throughout the process, attention is paid to the credibility and relevance of sources, ensuring that the review reflects a balanced and comprehensive understanding of the topic. The final output is a cohesive, interpretive account that not only summarizes existing knowledge but also proposes directions for future research.

This paper presents a narrative literature review based on a synthesis of empirical studies, meta-analyses, and systematic reviews. The primary sources were located through searches on academic databases and Google Scholar. The methodology for this review was to identify and synthesize findings on the key relationships between gamified/mobile learning, student engagement, scientific inquiry skills, and moderating variables.

For future research, a methodological approach focused on establishing causal claims is recommended:

➢ *Controlling for Prior Achievement:*
Future studies should use pre-test measures or value-added models to account for a student's existing knowledge and disentangle the effect of the intervention from their baseline skills.

➢ *Employing Experimental Designs:*
When feasible, studies should randomly assign students to different conditions, such as providing additional device or internet support, to estimate the direct causal effect of access.

➢ *Conducting Mediation Analyses:*
Researchers should test hypothesized causal pathways (e.g., that technology access leads to greater engagement, which in turn leads to improved skills) by collecting time-series usage data and conducting robust mediation analyses.

➢ *Measuring Usage Analytics:*
Logging app interactions (e.g., hours on task, experiments completed) is crucial to correlate behavioral variables with academic outcomes, providing objective measures of engagement.

➢ *Utilizing Mixed Methods:*
Incorporating qualitative data from interviews or focus groups can clarify the mechanisms behind the observed relationships and provide a richer understanding of student experiences.

V. RESULTS AND DISCUSSION

A. The Causal Link Between Technology and Inquiry

The use of gamified and mobile learning applications offers a structured environment that facilitates the core components of the scientific method, from forming a hypothesis to analyzing data. Unlike traditional methods that often lack hands-on experience, these technologies provide a platform for active, iterative learning.

➢ *Virtual Laboratories and Simulations:*
Mobile applications can function as virtual laboratories, enabling students to perform experiments that would be too costly or dangerous to conduct in a physical classroom. Students can manipulate variables and observe results in a simulated environment, which directly helps them develop essential inquiry skills like experiment design and data collection (Ahmed & Parsons, 2013; Husnaini & Chen, 2019). The ability to try, fail, and try again, a common feature in games, mirrors the iterative nature of the real-world scientific process.

➢ *Gamified Problem-Solving:*
By incorporating game elements like quests, challenges, and puzzles, these apps encourage students to apply scientific knowledge to solve complex problems. This approach moves beyond simple recall and promotes critical thinking and problem-solving, which are foundational to scientific inquiry (Kalogiannakis et al., 2021).

➢ *Real-Time Data Analysis:*
Modern smartphones are equipped with various sensors that applications can utilize to allow students to collect real-time data from their environment. This feature directly supports the inquiry skill of data interpretation and analysis, giving students hands-on experience with authentic scientific processes. Systematic reviews confirm that such mobile-supported inquiry designs frequently enhance inquiry processes and related outcomes (Liu et al., 2021; Suárez et al., 2018).

B. The Role of Engagement and Academic Performance

There is a strong positive correlation between student engagement and their academic performance in science, particularly among students who use mobile learning applications. The relationship is a causal cycle where enhanced engagement leads to behaviors that directly improve academic outcomes. Gamification elements like points, badges, and leaderboards act as powerful extrinsic motivators, providing a clear, quantifiable sense of progress and achievement (Hamari et al., 2014). This encourages students to complete tasks they might otherwise find uninteresting. Beyond external rewards, well-designed gamification also fosters intrinsic motivation by addressing students' fundamental psychological needs for competence, autonomy, and relatedness, as outlined by Self-Determination Theory (Ryan & Deci, 2000; Sailer et al., 2017).

Increased engagement in mobile learning environments results in improved academic outcomes. This is because engaged students tend to spend more time on tasks and exhibit greater persistence, which leads to enhanced mastery of concepts. Additionally, this engagement fosters deeper cognitive processing, encouraging students to move beyond rote memorization and engage in critical thinking and problem-solving. The magnitude of this correlation can vary, but the direction is almost always positive. While some studies report moderate effects, others show a very strong association where engagement accounts for a significant portion of the variance in academic performance (EA Journals). However, the effect of these elements can wane over time if they are not integrated meaningfully into the learning process.

C. The Moderating Role of Socio-Demographic Factors and Technology Access

Student socio-demographic characteristics and access to technology are causal factors that significantly influence their engagement with educational tools. These variables act as moderators, shaping the effectiveness of educational interventions. Therefore, understanding these characteristics is

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crucial for designing and implementing effective educational strategies.

- *Age and Grade Level*

A student's age and grade level are critical in determining their cognitive readiness and motivational drivers. While younger students may be driven by extrinsic rewards, older students require learning to be connected to personal interests to foster true engagement. Research indicates that students' capacity for complex reasoning and sustained motivation improves with age, suggesting that older students may be better equipped to handle the demands of app-based inquiry tasks (Icenogle et al., 2019; Towner, 2023).

- *Academic Track and Gender*

A student's academic track (e.g., STEM, TVL) has a direct causal link to their academic background and learning preferences. STEM students often have a stronger foundation in science, allowing gamified apps to foster higher-order inquiry skills, while for non-STEM students, these apps can bridge a knowledge gap. Similarly, gender can play a role in self-efficacy and interests. While some studies find no significant gender differences, others note that male students may respond more to competitive features while female students prefer collaborative ones. These differences, however, can be mitigated through inclusive design (Jia, 2020; Siddiq et al., 2019).

- *Location and Technology Access*

A student's location (urban vs. rural) and their access to technology are the most direct causal variables. The "digital divide" means that students in rural areas with limited access to stable internet and personal mobile devices are at a significant disadvantage (Estrañero, 2024; Livingstone & Helsper, 2007). Without consistent access, even the most well-designed app is rendered ineffective, as students cannot engage with real-time feedback, collaborative features, or virtual simulations. Research from the remote learning era provides clear evidence that technology access and skills are significant predictors of both participation and academic performance (So et al., 2020).

- *Personal Device Ownership and Usage*

Ownership of a personal smartphone or tablet and consistent internet access are foundational for effective use. Studies consistently show that students with reliable devices and connectivity engage more frequently and deeply, leading to improved scientific inquiry skills (Wang et al., 2022). The amount of time spent on school-related activities also matters, as higher engagement and greater exposure to instructional content directly correlates with better academic results (Kuş, 2025).

VI. CONCLUSION

Gamified and mobile learning applications mark a transformative step in science education by creating interactive, student-centered environments that mirror the processes of scientific inquiry. These tools allow learners to engage in hypothesis building, experimentation, and data analysis in ways that traditional methods often cannot replicate. By embedding gamification elements, they stimulate both intrinsic and extrinsic motivation, resulting in heightened engagement, deeper cognitive processing, and improved academic performance.

Despite these advantages, their effectiveness is not equally distributed among all learners. Socio-demographic factors such as age, academic track, gender, and especially access to technology significantly influence outcomes. Students in rural areas or those lacking reliable devices face systemic barriers that hinder their ability to benefit fully from these innovations. Thus, equitable implementation requires educators and policymakers to design strategies that are inclusive, context-sensitive, and responsive to diverse student needs.

Looking ahead, future research must move beyond correlational evidence to establish stronger causal claims, particularly within the Philippine educational context. Employing controlled experiments, mediation analyses, and detailed usage analytics will help identify the behavioral mechanisms that drive success. By addressing issues of digital equity and designing accessible, need-supportive interfaces, developers and educators can ensure that gamified and mobile learning applications truly empower all students to become active, engaged scientific thinkers capable of thriving in modern learning environments.

VII. DIRECTIONS FOR FURTHER RESEARCH

While existing literature supports the positive impact of gamified and mobile learning on scientific inquiry skills, several gaps remain that warrant further investigation. First, longitudinal studies are needed to assess the sustained effects of gamification on student motivation and academic performance over time. Many current studies focus on short-term outcomes, leaving questions about long-term retention and behavioral change unanswered.

Second, future research should explore the intersectionality of socio-demographic factors such as gender, academic track, and geographic location with technology access. Mixed-methods studies that combine quantitative performance metrics with qualitative insights from students and teachers could provide richer, context-sensitive data. Additionally, there is a need for culturally responsive design frameworks that adapt gamified learning tools to local educational contexts, particularly in underserved regions like rural Philippines. Finally, experimental studies comparing different gamification strategies (e.g., competitive vs.

collaborative) could help identify which elements are most effective for diverse learner profiles.

VIII. TRANSLATIONAL RESEARCH

The findings of this study may be best translated into practical school-based and community-based information products and implementation materials to guide teachers, learners, and stakeholders in adopting gamified and mobile learning to improve scientific inquiry skills. In particular, the results can be translated into: (1) a Teacher's Implementation Guide and Learning Activity Sheets (LAS) showing how to use gamified/mobile inquiry tasks while intentionally boosting engagement; (2) infographics, short explainer videos, and social media cards summarizing "how gamified mobile learning supports inquiry" and "how engagement improves performance," for students and parents; (3) Learning Action Cell (LAC) session modules, webinars, or school-based orientations to train teachers on inclusive gamification strategies (e.g., collaborative options, meaningful integration to prevent motivation from waning); and (4) an equity-focused access plan (offline/low-data alternatives, device-sharing protocols, printed equivalents, and scheduled connectivity support) to address the digital divide that moderates effectiveness, especially in underserved contexts. These materials may be disseminated through school communication channels, DepEd-level brief reports, community bulletin/wall postings for remote areas, and mass/social media platforms for wider awareness and adoption following the same dissemination approach reflected in the provided translational research sample.

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