Global Journal of Engineering and Technology Advances
eISSN: 2582-5003
Cross Ref DOI: 10.30574/gjeta
Journal homepage: https://gjeta.com/

(REVIEW ARTICLE)

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Design and development of a gamified Moodle-based online learning course integrating interactive videos and immersive activities to enhance student engagement in probability learning

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Global Journal of Engineering and Technology Advances, 2026, 28(01), 019–026

Publication history: Received on 25 May 2026; revised on 30 June 2026; accepted on 02 July 2026

Article DOI: https://doi.org/10.30574/gjeta.2026.28.1.0169

Abstract

The digital transformation of higher education has accelerated the adoption of online learning environments while simultaneously highlighting persistent challenges related to student engagement. These challenges are particularly evident in probability education, where abstract concepts and traditional teacher-centered approaches often hinder students' understanding and motivation. To address this issue, the present study proposes the design and development of a gamified online learning course integrating interactive videos and immersive activities within the Moodle learning management system to enhance undergraduate mathematics students' engagement in probability learning.

This study follows a Design and Development Research (DDR) methodology and adopts the ADDIE instructional design model as its methodological framework. The proposed learning environment is grounded in constructivism, social constructivism, cognitive load theory, and connectivism, while incorporating principles of instructional design, gamification, and interactive educational technologies.

The developed course consists of eight progressive learning modules integrating interactive videos, collaborative activities, formative assessments, and original educational games developed using HTML, CSS, and JavaScript, including Lucky Wheel Challenge, Stop Chrono Challenge, and Mission Weather Control. All learning resources are deployed within Moodle following a pedagogical sequence based on contextualization, knowledge structuring, reflection, and knowledge transfer, thereby promoting active and progressive learning.

The proposed instructional design model demonstrates how gamification, interactive videos, immersive learning activities, and collaborative tools can be coherently integrated into a single online learning environment. This work contributes to the field of instructional design for probability education by providing a reproducible pedagogical framework that can be adapted to other higher education disciplines. Future research will focus on experimentally evaluating the effectiveness of the proposed learning environment in enhancing student engagement and learning outcomes.

Keywords: Online learning; Moodle; Instructional design; Gamification; Interactive videos; Immersive learning activities; Student engagement; Probability education; Design and Development Research; ADDIE model.

1. Introduction

The digital transformation of higher education has profoundly reshaped teaching and learning practices by fostering the widespread adoption of online learning platforms and interactive digital environments. These technological

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advances have created new opportunities to design learning experiences that are more flexible, collaborative, and learner-centered. Nevertheless, maintaining student engagement remains one of the major challenges in online education, particularly in distance learning environments where traditional content-centered approaches often limit learners' motivation, active participation, and persistence (UNESCO, 2023; OECD, 2023; Fredricks et al., 2004).

Probability education represents a particularly challenging context in this regard. Because probability concepts are inherently abstract, many students experience difficulties in understanding and applying them when instruction relies primarily on theoretical explanations and conventional problem-solving exercises. Recent studies have demonstrated that integrating gamification, interactive videos, and immersive learning activities can promote more active learning experiences by enhancing students' cognitive, behavioral, and emotional engagement (Mayer, 2021; Kapp, 2012; Sailer & Homner, 2020).

In response to these challenges, the present study proposes the design and development of a gamified Moodle-based online learning course for undergraduate mathematics students. Guided by instructional design principles and the ADDIE model, the proposed learning environment integrates interactive videos, immersive activities, collaborative learning tools, formative assessment, and educational games to create a coherent, interactive, and learner-centered educational experience. By combining these complementary pedagogical strategies within a single learning environment, this study aims to contribute to innovative approaches for probability education while providing a reproducible instructional design framework that can be adapted to other higher education contexts.

The remainder of this paper is organized as follows. Section 2 presents the research context, followed by the research problem, research questions, and research objectives. The theoretical framework and research methodology are then described before presenting the design and development of the proposed learning environment. Finally, the discussion, conclusions, limitations, and future research directions are presented.

2. Research Context

The rapid advancement of digital technologies has significantly transformed higher education by expanding the use of Learning Management Systems (LMSs), such as Moodle. These platforms provide educators with powerful tools to organize learning resources, monitor student progress, facilitate communication, and support collaborative and interactive learning experiences. Despite these technological advances, many online learning environments remain predominantly content-oriented, offering limited opportunities for active student participation and sustained engagement (Bond et al., 2020; UNESCO, 2023).

This challenge is particularly evident in probability education, where students frequently encounter difficulties due to the abstract nature of probabilistic concepts. Although a wide range of digital learning resources is currently available, most of them continue to rely on traditional instructional approaches and make limited use of gamification, interactive videos, and immersive learning activities to actively engage learners and facilitate conceptual understanding.

Within this context, there is a growing need for innovative instructional designs that integrate these complementary pedagogical approaches into a coherent online learning environment. The present study addresses this need by proposing a **gamified Moodle-based online learning course** specifically designed for undergraduate mathematics students. The proposed learning environment combines instructional design principles, educational technologies, and active learning strategies to create an engaging and meaningful learning experience in probability education.

3. Research Problem

The widespread adoption of online learning environments has considerably improved access to educational resources in higher education. However, many online courses continue to rely primarily on content delivery and conventional instructional approaches, providing limited opportunities for learner interaction, active participation, and meaningful engagement. These limitations are particularly evident in probability education, where the abstract nature of probabilistic concepts often makes learning challenging when traditional teaching methods are employed.

Although recent advances in educational technologies have introduced numerous digital learning solutions, few instructional designs successfully integrate gamification, interactive videos, immersive learning activities, and collaborative tools into a coherent pedagogical framework. Consequently, there remains a need for innovative learning environments capable of fostering student engagement while facilitating the understanding of complex probability concepts.

The present study addresses this gap by proposing the design and development of a gamified Moodle-based online learning course that combines these complementary pedagogical approaches within a single instructional framework.

3.1. Main Research Question

How can a gamified Moodle-based online learning course integrating interactive videos and immersive learning activities be designed and developed to enhance undergraduate mathematics students' engagement in probability learning?

3.2. Specific Research Questions

To address the main research question, the study seeks to answer the following questions:

- How can gamification, interactive videos, and immersive learning activities be coherently integrated into a Moodle-based learning environment?
- How can learning activities be designed to promote students' active participation and progressive knowledge construction?
- To what extent can such an instructional design contribute to enhancing student engagement in probability learning?
- How can instructional design principles be applied to ensure alignment among learning objectives, learning activities, and assessment strategies?

4. Originality and Significance of the Study

The originality of this study lies in the design of an integrated online learning environment that combines gamification, interactive videos, immersive learning activities, collaborative tools, and formative assessment within a single Moodle-based instructional framework. Unlike many existing online learning environments, which often implement these approaches independently, the proposed course integrates them into a coherent pedagogical sequence structured around four learning phases: contextualization, knowledge structuring, reflection, and knowledge transfer.

A second contribution of this research is the development of three original educational games—Lucky Wheel Challenge, Stop Chrono Challenge, and Mission Weather Control—designed using HTML, CSS, and JavaScript and fully integrated into Moodle. Rather than serving as conventional assessment tools, these games create authentic learning situations that enable students to experience and explore abstract probability concepts through interaction and experimentation.

Finally, this study contributes to the field of instructional design by proposing a reproducible pedagogical framework for probability education that can be adapted to other higher education disciplines seeking to enhance learner engagement through educational technologies.

Research Objectives

- General Objective

The primary objective of this study is to design and develop a gamified Moodle-based online learning course integrating interactive videos and immersive learning activities to enhance undergraduate mathematics students' engagement in probability learning.

- Specific Objectives
- To achieve this objective, the study pursues the following specific objectives:
- To analyze the learning needs of undergraduate mathematics students in the field of probability.
- To design a pedagogically coherent instructional framework based on the **ADDIE instructional design model** and established instructional design principles.
- To develop a Moodle-based online learning course integrating interactive learning resources, collaborative activities, formative assessment, and gamification elements.
- To design and implement original educational games that promote students' conceptual understanding of probability through interaction, experimentation, and active learning.
- To propose a reproducible instructional design framework that can be adapted to other higher education disciplines seeking to enhance learner engagement through educational technologies.

5. Theoretical Framework

The design and development of the proposed online learning course are grounded in a comprehensive theoretical framework that integrates learning theories, instructional design principles, gamification, and interactive educational technologies. This theoretical foundation informed both the pedagogical and technological decisions adopted throughout the development process.

5.1. Learning Theories

The proposed learning environment is primarily informed by constructivism and social constructivism, which view learners as active participants in the construction of knowledge through exploration, experience, and social interaction (Piaget, 1970; Vygotsky, 1978). These perspectives support the use of learner-centered activities that encourage collaboration, problem-solving, and knowledge construction.

The instructional design also draws upon Cognitive Load Theory (Sweller, 1988), which emphasizes the importance of organizing instructional content in a progressive manner to reduce unnecessary cognitive load and facilitate meaningful learning. In addition, Connectivism (Siemens, 2005) provides a theoretical rationale for using Moodle as a digital learning environment that promotes collaboration, resource sharing, and networked learning.

5.2. Instructional Design

The instructional design of the course follows the ADDIE model, which provides a systematic framework for analyzing learning needs, designing instructional strategies, developing educational resources, and implementing the learning environment. To ensure pedagogical coherence, learning objectives were formulated according to the revised Bloom's Taxonomy, while constructive alignment was applied to establish consistency among learning objectives, instructional activities, and assessment strategies (Branch, 2009; Anderson & Krathwohl, 2001; Biggs, 1996).

5.3. Gamification and Student Engagement

Gamification represents one of the core components of the proposed instructional design. The integration of challenges, badges, immediate feedback, and progressive learning pathways was intended to enhance students' motivation, engagement, and persistence throughout the learning process. In addition to these game elements, three original educational games—Lucky Wheel Challenge, Stop Chrono Challenge, and Mission Weather Control—were specifically designed to transform abstract probability concepts into authentic learning experiences where students actively construct knowledge through interaction and experimentation (Kapp, 2012; Sailer & Homner, 2020).

5.4. Interactive Videos and Immersive Learning Activities

Interactive videos and immersive learning activities play a central role in promoting active learning by encouraging learners to interact continuously with instructional content through embedded questions, feedback, decision-making tasks, and contextualized learning scenarios. Within the proposed course, these technologies contribute to making probability concepts more concrete and meaningful while supporting learners' engagement and conceptual understanding (Mayer, 2021; Brame, 2016).

5.5. Synthesis of the Theoretical Framework

The integration of learning theories, instructional design principles, gamification, and interactive educational technologies provided a coherent foundation for the development of the proposed Moodle-based learning environment. This theoretical framework guided all pedagogical, technological, and methodological decisions throughout the design process and served as the basis for the instructional model presented in the following sections.

6. Research Methodology

6.1. Research Design

This study adopts a Design and Development Research (DDR) approach, which is particularly appropriate for the design, development, and refinement of innovative educational interventions. Unlike experimental research, DDR focuses on developing practical solutions to educational challenges while grounding the design process in established theoretical foundations and systematic instructional design principles. In this study, the DDR methodology provides the framework for designing a gamified online learning environment aimed at enhancing student engagement in probability education.

6.2. Instructional Design Process

The development of the proposed learning environment followed the ADDIE instructional design model, which structured the project through five iterative phases: Analysis, Design, Development, Implementation, and Evaluation. The analysis phase focused on identifying learners' needs and instructional requirements. The design phase involved defining learning objectives, selecting instructional strategies, and developing the pedagogical architecture of the course. During the development phase, digital learning resources, educational games, and multimedia materials were created and integrated into Moodle. Due to time constraints, the implementation was limited to the deployment of the learning environment, while the evaluation phase remains a direction for future research.

6.3. Research Context

The proposed online learning course was designed for undergraduate mathematics students enrolled in probability courses. The entire learning experience is delivered through the Moodle Learning Management System (LMS) and is organized into eight sequential learning modules distributed over a four-month period. Each module follows a common instructional structure designed to promote progressive knowledge acquisition and active learner engagement.

6.4. Development Tools

Several complementary technologies were employed throughout the development process. Moodle served as the central Learning Management System, while H5P was used to create interactive videos. Original educational games were developed using HTML, CSS, and JavaScript within Visual Studio Code. User interface prototypes were designed using Figma, instructional videos were produced and edited with VN Video Editor, and Adobe Podcast was employed to enhance audio quality by reducing background noise and improving voice clarity.

6.5. Instructional Architecture

All learning modules follow a unified instructional architecture consisting of four successive learning phases: Contextualization, Knowledge Structuring, Reflection, and Knowledge Transfer. This pedagogical sequence reflects both constructivist and inductive learning approaches, allowing students to explore authentic problem situations before formalizing theoretical concepts and applying them in new learning contexts. This instructional architecture ensures consistency throughout the course while promoting active participation, conceptual understanding, and progressive knowledge construction.

7. Design and Development of the Learning Environment

The proposed online learning course was designed following a systematic instructional design process based on the ADDIE model and fully implemented within the Moodle Learning Management System (LMS). The course targets undergraduate mathematics students and consists of eight sequential learning modules distributed over a four-month learning period. Each module follows a common instructional structure organized into four pedagogical phases: Contextualization, Knowledge Structuring, Reflection, and Knowledge Transfer, ensuring consistency and progressive knowledge development throughout the learning process.

The instructional design adopts both inductive and constructivist approaches, enabling students to explore authentic problem situations before formalizing theoretical concepts. This pedagogical strategy encourages learners to actively construct knowledge through inquiry, experimentation, collaboration, and reflective learning. To further support collaborative learning, the course incorporates discussion forums, wikis, pair-based learning activities, and synchronous online meetings, thereby promoting interaction, knowledge sharing, and peer learning.

To enhance learner engagement, the proposed learning environment integrates multiple complementary instructional components, including interactive videos, formative assessment, collaborative activities, gamification elements, and original educational games specifically designed for this study. Gamification strategies such as badges, learning challenges, immediate feedback, and progressive learning pathways were incorporated to foster motivation, persistence, and active participation throughout the course.

A distinctive contribution of this research is the development of three original educational games—Lucky Wheel Challenge, Stop Chrono Challenge, and Mission Weather Control—which were designed using HTML, CSS, and JavaScript and subsequently integrated into Moodle. Unlike conventional quizzes or assessment activities, these games immerse learners in authentic problem-solving situations where abstract probability concepts are explored through interaction, experimentation, and immediate feedback. Consequently, game-based activities become an integral component of the learning process rather than simple assessment tools.

The development of the learning resources relied on several complementary technologies. User interface prototypes were created using Figma, while educational games were programmed in Visual Studio Code. Instructional videos were produced and edited with VN Video Editor, and Adobe Podcast was used to enhance audio quality by reducing background noise and improving speech clarity. Furthermore, custom animations, such as the rotating die, were developed using HTML, CSS, and JavaScript, recorded as video sequences, and subsequently embedded into H5P interactive videos, thereby enriching the multimedia learning experience.

Finally, all instructional resources were integrated into Moodle to create a unified, interactive, and learner-centered online learning environment. The coherent integration of multimedia resources, collaborative learning activities, formative assessment, gamification mechanisms, and educational games resulted in a comprehensive instructional ecosystem designed to enhance learner engagement, facilitate conceptual understanding, and promote meaningful learning in probability education.

8. Discussion

The primary objective of this study was to design and develop a gamified Moodle-based online learning course integrating interactive videos and immersive learning activities to enhance undergraduate mathematics students' engagement in probability learning. The proposed learning environment demonstrates that instructional design principles, gamification strategies, and interactive educational technologies can be effectively integrated into a coherent pedagogical framework that promotes active and learner-centered learning.

The instructional choices adopted in this study are consistent with previous research highlighting the educational benefits of multimedia learning (Mayer, 2021), gamification (Kapp, 2012; Sailer & Homner, 2020), and constructivist learning approaches (Piaget, 1970; Vygotsky, 1978). The integration of interactive videos, collaborative learning activities, educational games, and formative assessment creates multiple opportunities for learner interaction, immediate feedback, and progressive knowledge construction, thereby supporting both conceptual understanding and sustained engagement.

Unlike many existing online learning environments that employ gamification primarily as a motivational strategy, the proposed learning environment integrates gamification as a fundamental component of the instructional design. Educational games are not used merely for assessment purposes; instead, they constitute authentic learning experiences through which students explore, experiment with, and progressively construct probability concepts before formal theoretical instruction. This pedagogical integration represents one of the principal contributions of the present study.

Another significant contribution lies in the development of three original educational games—Lucky Wheel Challenge, Stop Chrono Challenge, and Mission Weather Control—designed specifically for probability education and implemented using HTML, CSS, and JavaScript before being integrated into Moodle. These games illustrate how educational technologies can be combined with sound instructional design principles to transform abstract mathematical concepts into engaging and meaningful learning experiences.

Despite these contributions, the study has certain limitations. Due to time constraints, the proposed learning environment has not yet been experimentally evaluated with undergraduate students. Consequently, the effectiveness of the instructional design in improving learner engagement and academic performance remains to be empirically validated. Future experimental studies comparing the proposed learning environment with more traditional instructional approaches would provide valuable evidence regarding its educational effectiveness.

9. Conclusion

This study presented the design and development of a gamified Moodle-based online learning course integrating interactive videos and immersive learning activities to enhance undergraduate mathematics students' engagement in probability learning. Guided by the Design and Development Research (DDR) methodology and the ADDIE instructional design model, the proposed learning environment combines learning theories, instructional design principles, gamification, and interactive educational technologies within a coherent pedagogical framework.

The resulting instructional environment demonstrates how multiple educational strategies—including interactive videos, collaborative learning activities, formative assessment, gamification mechanisms, and original educational games—can be effectively integrated into a single online learning ecosystem. Beyond its technological implementation,

the proposed course offers a reproducible instructional design framework that may support the development of engaging online learning environments in probability education and other higher education disciplines.

Although the present study focused primarily on the design and development of the learning environment, it establishes a solid foundation for future empirical research. Evaluating the effectiveness of the proposed instructional design in enhancing student engagement, motivation, and learning outcomes represents an important direction for future studies. Furthermore, the instructional framework developed in this research may be adapted and extended to other educational contexts and emerging digital learning environments.

Limitations and Future Research

Despite its contributions, this study has several limitations that should be acknowledged. First, the research focused primarily on the design and development of a gamified Moodle-based online learning course integrating interactive videos and immersive learning activities. Owing to the time constraints associated with the project, the proposed learning environment was not experimentally evaluated with undergraduate mathematics students. Consequently, its impact on learner engagement, motivation, academic achievement, and learning outcomes has not yet been empirically validated.

Second, the proposed instructional design was specifically developed for probability education within an undergraduate mathematics program. Although the pedagogical framework is expected to be transferable to other educational contexts, its applicability to different disciplines requires further adaptation and validation.

Future research should therefore focus on conducting experimental and quasi-experimental studies to evaluate the effectiveness of the proposed learning environment using both quantitative and qualitative research methods. Particular attention should be given to examining the individual and combined effects of gamification, interactive videos, immersive learning activities, and educational games on the cognitive, behavioral, and emotional dimensions of student engagement.

Furthermore, future studies may explore the integration of emerging educational technologies, such as artificial intelligence, learning analytics, adaptive learning systems, virtual reality, and augmented reality, to further personalize learning experiences and improve instructional effectiveness. The proposed instructional design framework may also be adapted to other STEM disciplines and broader higher education contexts, thereby contributing to the development of innovative, learner-centered digital learning environments.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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