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Research Article

Toward a Lecturer-Centered Gamification Framework in Pedagogical Design in STEM Higher Education

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Abstract. Gamification has been widely implemented in STEM based higher education to increase student engagement and motivation. However, the conceptual foundation is still dominated by a student-centered or system-centered approach. This study aims to examine the extent to which lecturer-centered perspectives are integrated in gamification-based STEM learning. By following the PRISMA 2020 protocol, a total of 1,321 initial documents were identified from the Scopus database. After going through a rigorous screening and feasibility assessment process, 97 peer-reviewed journal articles were evaluated, and only 11 studies (11.3%) demonstrated structured pedagogical modeling by explicitly placing lecturers as instructional designers. Bibliometric analysis revealed that the dominant themes revolved around gamification, student engagement, engineering education, and game-based learning, while instructional design and the role of lecturers were in a less central position in the main discourse. The thematic synthesis identifies four main dimensions, namely the digital competence of lecturers, the cognitive load in gamification design, the alignment of lecturer and student motivation, and the need for a systematic pedagogical design framework. These findings show a significant gap in the model that systematically guides lecturers in designing pedagogically aligned gamification in the STEM context. In response, this study proposes a conceptual framework of Lecturer-Centered Gamification (LCG) structured in pre-game, in-game, and post-game phases, emphasizing pedagogical intentionality, interaction design, and systematic evaluation. This study makes a theoretical contribution by repositioning the role of lecturers as the core of gamification architecture, as well as practical contributions as the foundation for the development of sustainable and scalable gamified learning designs in higher education.

Keywords: Gamification; Instructional Design; Lecturer Centered; Pedagogical; STEM Higher Education.

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1. Introduction

The development of the industry 4.0 and 5.0 requires a transformation in the education system, especially in the fields of Science, Technology, Engineering, and Mathematics to produce graduates who have the ability to think critically and innovatively [1], [2]. STEM education as a meta-discipline that emphasizes problem-based approaches and active learning is crucial in facing the convergence of advanced technologies [3]. However, the implementation of this approach often encounters obstacles in integrating technology effectively, especially when educators are required to switch from face-to-face learning to online learning which requires creativity and innovation in pedagogical design [4].

Gamification comes as a strategic solution that integrates elements of gaming into the learning context to increase student engagement and motivation [5], [6]. Various meta-analysis studies show that the application of gamification has a significant positive impact on student learning outcomes in STEM-based subjects, with an effect size value of 0.5492 [7]. However, the existing research focus is still generally limited to a student-centered perspective, while pedagogical design challenges from a lecturer-centered perspective in the context of STEM higher education have not been explored in depth [1]. This gap is important

to fill considering the role of lecturers as learning designers that determine the success of integrating technology and pedagogical strategies in a dynamic academic environment [2], [5].

Therefore, this systematic literature review aims to identify and analyze the pedagogical design challenges faced by lecturers in implementing gamification, as well as examine the shift in focus from a student-centered approach to the role of lecturers as the main controller of learning strategies [8], [9]. This research focuses on how lecturers manage pedagogical transitions and overcome technical and conceptual barriers when designing effective and challenging learning environments for STEM students [5], [7]. In addition, this change in learning paradigm also requires complex pedagogical adaptation, considering that STEM as an interdisciplinary discipline requires a change from traditional approaches to support mastery of science domains that are often considered abstract and difficult to understand by students [7], [10].

Complex concepts in engineering and technology require students to master high-level thinking skills in order for learning to run effectively, although these challenges can often be overcome through high motivation to learn [7]. This encourages the use of game elements such as points, levels, and challenges to create a more enjoyable learning atmosphere and stimulate students' creativity and critical thinking skills [9], [11]. The challenge element in gamification plays an important role in providing encouragement to students to face problem-based problems that are tailored to their abilities [5]. However, the successful implementation of these strategies is highly dependent on educators' readiness to adopt new methods, which often requires additional training to prepare them to design and manage integrated learning experiences [12].

This role transformation requires lecturers to not only function as material presenters, but also as facilitators and designers of learning experiences who are able to design contextual projects and anticipate adequate logistical and technological needs [12]. In addition, the limited time that lecturers have in developing innovative learning strategies is often a major obstacle, considering that the process of designing and implementing gamification requires a significant allocation of time to balance academic workload and instructional design needs [13]. This paradigm shift also poses significant challenges for lecturers who are accustomed to traditional teaching methods, where they must transition to become facilitators who support students' active learning [14]. This transition requires a gradual adaptation process, where lecturers need to obtain adequate training and institutional support to understand and implement project-based or gamification approaches effectively [15].

2. Literature Review

Theoretical and Strategic Frameworks in STEM Gamification In addition to the basic foundations of gamification, implementation in STEM higher education is heavily influenced by several key frameworks. Mechanics–Dynamics–Aesthetics (MDA) structures the learning experience through the integration of rules (mechanical), progression (dynamic), and narrative or immersion (aesthetics) to increase engagement [16], [17]. In addition, the Strategic Gamification Framework (SGF) has emerged as an approach to transform traditional STEM projects into interactive "quests" that emphasize epic missions, progress tracking, and ongoing feedback to encourage student collaboration and creativity [16], [18], [19]. Robust pedagogical validation also often refers to the ARCS (Attention, Relevance, Confidence, Satisfaction) and Self-Determination Theory (SDT) models to ensure that the elements of play support the autonomy, competence, and connectedness needs of students [20], [21].

The Multidimensional Impact of Game Mechanics Empirical evidence shows that the integration of game elements such as Points, Badges, and Leaderboards (PBL) consistently increases healthy competition motivation [22], [23], [24]. However, recent research emphasizes that narrative and role-play have a more profound impact on critical thinking and problem-solving skills, especially when aligned with complex STEM course content [25], [26], [27]. Transforming the Role of Lecturers and Multi-Tiered Scaffolding In the Lecturer-Centered Gamification (LCG) model, lecturers are no longer just material presenters but transform into learning architects and mentors [17], [19].

Integration of AI and Immersive Technologies in LCG Recent trends (2020–2025) indicate a shift towards gamification powered by Artificial Intelligence (AI) and immersive technologies. Generative AI and Large Language Models (LLMs) are starting to be used by lecturers to generate dynamic content and provide personalized feedback in real-time [28], [29], [30]. Meanwhile, immersive platforms such as Augmented Reality (AR), Virtual Reality (VR), and the Metaverse (e.g. "Math City") offer multisensory learning environments that

improve memory retention and understanding of abstract concepts in STEM [31], [32]. The use of Learning Analytics (LA) through monitoring dashboards also allows lecturers to intervene early for students at risk of falling behind [33], [34].

Gamification has increasingly been adopted in higher education as an instructional innovation aimed at enhancing student engagement, motivation, and learning outcomes, particularly in STEM disciplines. Conceptually, gamification refers to the application of game design elements in non-game contexts [35]. In STEM education, gamification is frequently employed to support problem-based learning, simulation-based instruction, and collaborative activities that require active cognitive engagement. Empirical evidence suggests that elements such as points, badges, leaderboards, and immediate feedback can positively influence student motivation and participation [36], [37]. However, most of these studies focus primarily on student outcomes, often overlooking the instructional design processes undertaken by lecturers.

Subsequent research emphasizes that the effectiveness of gamification depends largely on pedagogical alignment rather than the mere inclusion of game mechanics. The integration of gamification into instructional contexts requires coherence between learning objectives, activities, and assessment strategies [38]. Frameworks such as Mechanics–Dynamics–Aesthetics and constructivist learning principles [39] have been applied to guide gamified learning environments. Nevertheless, these frameworks typically prioritize learner experience over the lecturer's design process. As a result, gamification is frequently implemented as a technological enhancement within Learning Management Systems rather than as a structured pedagogical strategy [40], [41].

Emerging literature has begun to address the challenges lecturers face in designing gamified learning environments. These challenges include limited digital competence, increased cognitive workload, and difficulties in aligning game mechanics with complex STEM learning outcomes [42], [43]. Cognitive Load Theory highlights that excessive design complexity may reduce instructional effectiveness if not carefully managed [43]. Additionally, motivational theories such as Self-Determination Theory suggest that sustainable gamification requires alignment between intrinsic and extrinsic motivational factors for both students and instructors [44]. Without considering lecturer readiness and motivation, gamification initiatives risk becoming superficial or unsustainable.

Despite the rapid growth of gamification research in STEM education, systematic reviews indicate that lecturer-centered models remain underdeveloped [45], [46]. Most studies evaluate student engagement metrics or academic performance but do not propose comprehensive frameworks guiding lecturers through structured design, implementation, and reflective evaluation phases. This gap highlights the need for a Lecturer-Centered Gamification (LCG) approach that positions lecturers as central instructional architects. Developing a structured LCG model is therefore essential to bridge the divide between gamification theory and pedagogical design practice in STEM higher education.

3. Proposed Method

This study employed a Systematic Literature Review (SLR) approach to map the current state of research on Lecturer-Centered Gamification (LCG) within the context of STEM higher education. The review process was conducted systematically and transparently following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure methodological rigor and replicability [47]. The primary objective of this review was to identify conceptual characteristics, design components, and research gaps related to the role of lecturers in gamification implementation. The SLR approach was selected because it enables a structured synthesis of interdisciplinary literature, particularly across educational technology, information systems, and STEM education domains.

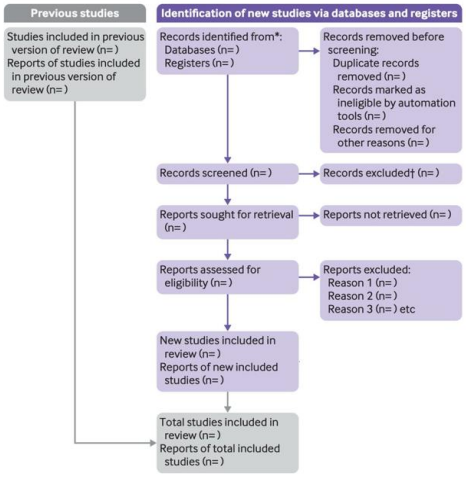


Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)

Method

Data collection was carried out through a comprehensive literature search in reputable academic Scopus databases using a structured Boolean query combining four key includinggamification or game-based learning, lecturer/teacher-centered or instructional design perspectives, STEM education context, and Interactivity or engagement.

```
TITLE-ABS-KEY (
  gamification OR "game-based learning" OR "gamified learning"
)
AND TITLE-ABS-KEY (
  "lecturer centered" OR "teacher-centered" OR "instructor-centered"
  OR "lecturer role" OR "teacher role"
  OR "instructional design" OR "learning design"
)
AND TITLE-ABS-KEY (
  STEM OR "STEM education"
  OR "science education" OR "engineering education"
  OR "computer science education"
)
AND TITLE-ABS-KEY (
  interactivity OR engagement OR interaction
  OR "learning interaction" OR "student engagement"
)
```

Figure 2. Boolean search keywords

The initial search yielded 1,321 records prior to filtering. The dataset was subsequently limited based on document type (journal articles), subject area (Computer Science and related STEM fields), language (English), and publication period (2020-2026). All references were exported in bibliographic format and screened for duplicate entries before proceeding to further selection stages.

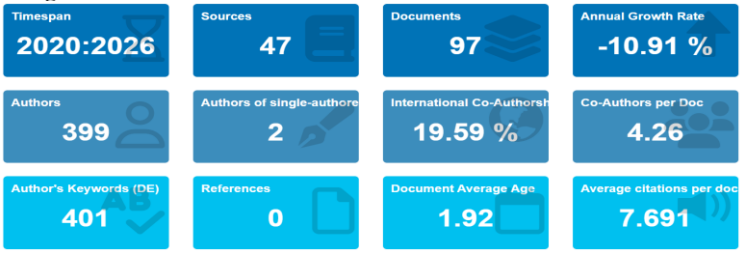


Figure 3. Dataset overview showing publication counts, mean citations, authors per document, and international collaboration.

The screening process consisted of two main steps, title and abstract screening followed by full-text review. Inclusion criteria required peer-reviewed journal articles addressing gamification in STEM higher education and explicitly linking instructional design, lecturer roles, or pedagogical structures to interactivity or engagement outcomes. Studies focusing on K-12 contexts, purely technical system descriptions without pedagogical dimensions, or lacking methodological transparency were excluded from the analysis. This selection process resulted in a final corpus of relevant studies that were subsequently analyzed through bibliometric and thematic approaches.

Data analysis was conducted in two stages. First, bibliometric analysis was employed to map publication trends, keyword co-occurrence networks, and thematic clusters in order to identify dominant research patterns and the positioning of LCG within the broader

gamification literature in STEM education. Second, a qualitative thematic analysis was performed on the selected articles to identify conceptual dimensions, lecturer roles, design challenges, and reported forms of interactivity. The synthesized findings were then used to develop an initial conceptual framework of the Lecturer-Centered Gamification (LCG) model, structured around pre-game, in-game, and post-game phases as a systematic pedagogical design architecture.

4. Results and Discussion

Result

Descriptive Result

The systematic screening process presented in Table 1. resulting in a final corpus of 11 core studies that met all inclusion and eligibility criteria. Of the 97 journal articles that have been screened in the early stages, as many as 12 studies were excluded because the context focused on K–12 education. A total of 44 other studies were dropped after not explicitly addressing the role of lecturers or the instructional design dimension, although discussions about gamification in higher education have been raised. At the stage of the full-text eligibility assessment, an additional 30 studies were excluded due to insufficient pedagogical depth, characterized by the absence of structured modeling or empirical validation of the instructional design process. Thus, only 11 studies (11.3% of the corpus screened) showed a comprehensive lecturer-centred pedagogical structure accompanied by an evaluation component. This substantial reduction indicates that research that focuses strictly on Lecturer-Centered Gamification is still limited in the treasure trove of gamification literature in the broader STEM realm.

Table 1. Core LCG Studies

No	Title	Year	Source	Quartile
1	Narrative-Driven Digital Gamification for Motivation and Presence: Preservice Teachers' Experiences in a Science Education Course	2025	*Computers*	Q2
2	Validation of the Player Personality and Dynamics Scale	2025	*Applied Sciences*	Q2
3	Synergizing STEM and ELA: Exploring How Small-Group Interactions Shape Design Decisions in an Engineering Design-Based Unit	2025	*Education Sciences*	Q1
4	The Creation and Evaluation of an AI Assistant (GPT) for Educational Experience Design	2025	*Information*	Q2
5	Game-D: Development of an Educational Game Using a Line Follower Robot on Straight Motion Material	2025	*IJ of Information and Education Technology*	Q3
6	A Gamified Active-Learning Proposal for Higher-Education Heterogeneous STEM Courses	2025	*Education Sciences*	Q1
7	Augmented Sensory Experience and Retention: ASER Framework	2025	*IJ Advanced Computer Science*	Q3
8	Exploring Pre-Service Teachers' Perspectives on the Integration of Digital Game-Based Learning for Sustainable STEM Education	2024	*Sustainability*	Q2
9	Level up your coding: a systematic review of personalized, cognitive, and gamified learning in programming education	2024	*PeerJ Computer Science*	Q1
10	Investigating Factors Contributing To Student Disengagement and Ownership In Learning: A Case	2024	*JITE: Innovations in Practice*	Q2

No	Title	Year	Source	Quartile
	Study Of Undergraduate Engineering Students			
11	The transportability of a game-based learning approach to undergraduate mechanical engineering education: Effects on student conceptual understanding, engagement, and experience	2020	*Sustainability*	Q2

The temporal distribution of the screened studies shows a fairly sharp increase in publications in the period 2024 to 2025, reflecting the increasing academic interest in gamification-based learning in the post-pandemic era of digital transformation. Nevertheless, most publications, especially before 2023, place more emphasis on student engagement, motivation, or technology utilization than on lecturer-centric instructional architecture. Even among the 41 studies that passed the second screening stage, the majority still positioned lecturers as facilitators, not instructional designers. This pattern suggests that although gamification research is evolving quantitatively, its conceptual orientation is still dominated by a student-centered approach.

In terms of publication output and research design, these studies are spread across cross-disciplinary journals in the fields of educational technology, applied science, and computer science. Quasi-experimental and mixed-method approaches are the most commonly used, with a focus on measurement on student performance or engagement. Explicit modeling of pedagogical quality, lecturer orchestration strategies, or structured design phases is relatively rare. In various STEM disciplines such as computer science, engineering, or science education, gamification is more often applied as an intervention at the course level only, without a systematic explanation of the design architecture. Figure 3 presents a PRISMA flowchart illustrating the systematic process of data search, screening, eligibility assessment, and final inclusion of studies in the Lecturer-Centered Gamification (LCG) systematic literature review.

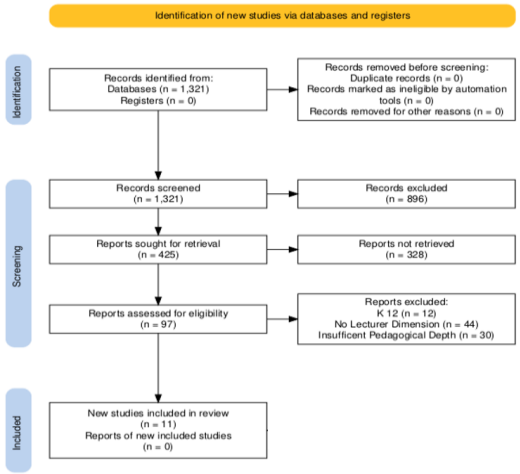


Figure 3. PRISMA flowchart for data search and extraction

Bibliometric Landscape

The visualization of "Sources' Production over Time" in Figure 4 shows a significant cumulative increase in publications during the 2023–2026 period, especially in journals such as Education Sciences, Applied Sciences, and IEEE Access. This surge reflects the acceleration of gamification research in the context of STEM education in line with the increasingly massive global digital transformation.

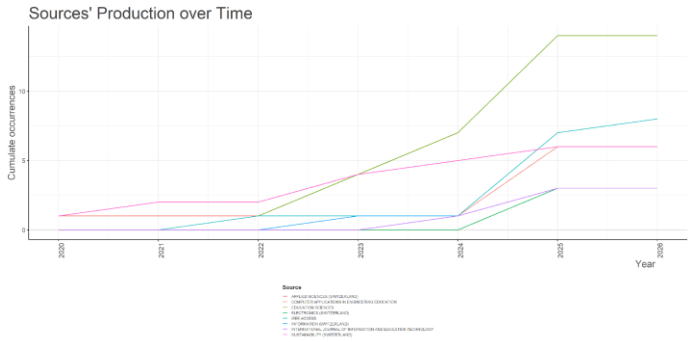


Figure 4. Sources production over time highlighting leading journals

The analysis of "Trend Topics" in Figure 5. shows that terms such as gamification, engineering education, students, and game-based learning dominate the frequency and duration of occurrence during the 2023-2026 period.

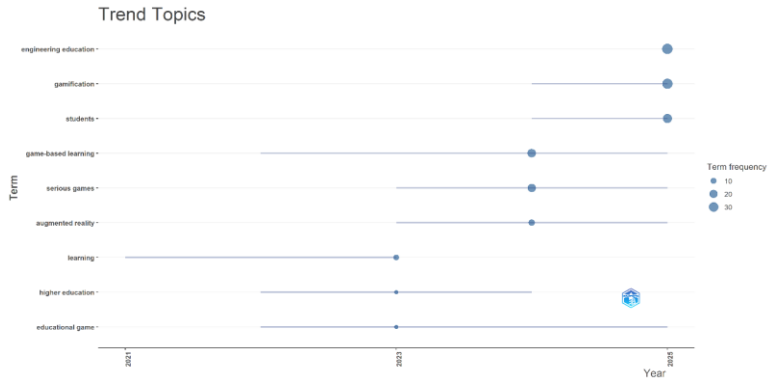


Figure 5. Trend Topics

The keyword "Co-occurrence network" map in figure 6. shows three main clusters, namely the student motivation and engagement cluster (centred on gamification, students, and motivation), the engineering education and human-computer interaction cluster (centred on engineering education and human-computer interaction), and the serious games and game-based learning cluster.

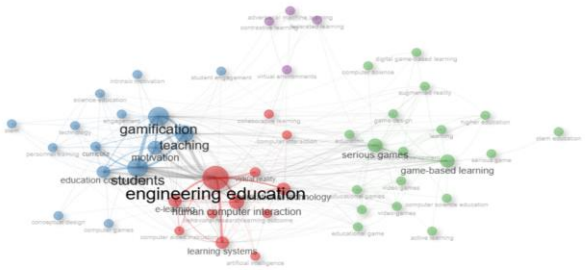


Figure 6. Co occurrence Network

Thematic Synthesis

Thematic map in figure 7. shows that there is an interesting imbalance in the development of gamification research in STEM-based higher education. Themes such as game-based learning and serious games appear conceptually mature and take a central position in literature, indicating that game-based approaches are well established and academically strongly integrated. However, the developing discourse is still dominated by the issue of student involvement and technological innovation. Terms such as gamification, students, and engineering education often appear and are considered relevant, but the instructional design process is rarely positioned as the main foundation of such interventions. Interestingly, instructional design is actually in the niche quadrant which means it has theoretical depth, but it is not yet firmly connected to the mainstream of gamification research. This condition shows a subtle but significant conceptual gap: gamification is more often studied in terms of its impact on students than in terms of how lecturers design and orchestrate the learning systematically. Overall, this landscape shows that literature is still driven by student

orientation and technology, while lecturer-centric pedagogical architecture has not been the main focus. Therefore, the development of a Lecturer-Centered Gamification (LCG) framework is essential to restore instructional design as a central element in gamification-based STEM learning.

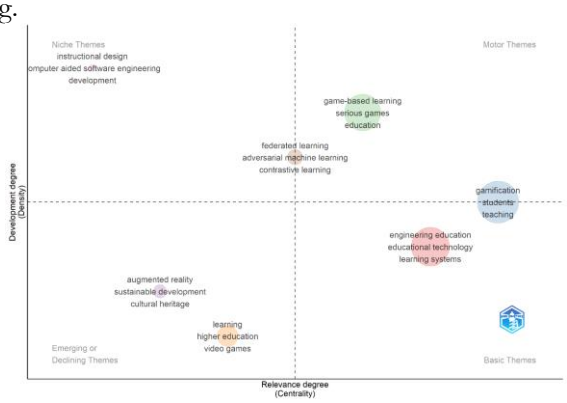


Figure 7. Thematic Map

Disscussion

Lecturer-Centered Gap Analysis

The findings of this study show that there is a fairly clear inequality in the gamification literature in STEM-based higher education, where lecturer-centric perspectives are still very limited. Although gamification has been extensively researched, only a small number of studies explicitly model pedagogical structures by placing lecturers as the main actors of learning design. Most research focuses more on student engagement outcomes and technological innovation, while lecturers are often positioned only as implementers, rather than instructional architects. This condition reflects a broader conceptual limitation: gamification is more often understood as an intervention for students than as a pedagogical design process systematically designed and orchestrated by lecturers. Therefore, it is necessary to reposition the role of lecturers from mere facilitators to main designers in the gamification ecosystem, which is the basis for the development of the Lecturer-Centered Gamification (LCG) framework.

Interactivity Implications

The results of the review show that interactivity in gamification-based STEM learning is still often understood narrowly as an interaction between students and digital systems. Many studies assess interactivity through the presence of features such as points, badges, leaderboards, augmented reality, or AI-based systems, as if the presence of such technology automatically creates interactive learning. In fact, meaningful interactivity is not only born from the system's response to users, but also from how the learning experience is designed and directed. Relatively few studies have explored how lecturers consciously form patterns of interaction, manage collaborative dynamics in the classroom, or align game mechanics with the learning outcomes they want to achieve. When the focus is too heavy on technology, interactivity risks being reduced to mere surface activities, rather than in-depth pedagogical processes. The lecturer-centered perspective offers a more comprehensive perspective by looking at interactivity because of an intentionally designed orchestration of learning integrating cognitive, social, and motivational aspects. Within the framework of LCG, interactivity is not just a feature of the system, but rather a pedagogical strategy that is designed gradually through the pre-game, in-game, and post-game phases.

Effectiveness Evaluation Insights

Most of the studies reviewed still assess gamification success from short-term indicators, such as increased student motivation, engagement levels, or academic achievement. While these measures are important, they tend to look at effectiveness only from the surface of learning outcomes, without exploring how the quality of the learning design itself affects the sustainability of its implementation. Relatively few studies have considered lecturer workloads, the complexity of designing gamification activities, or the alignment between game mechanics and pedagogical objectives as part of the evaluation. The lecturer-centered approach looks at effectiveness more comprehensively, measured not only by changes in students, but also by how aligned the learning design is designed, how adaptive it is in the classroom, and how realistic the model is in everyday practice. In the LCG model, the post-game phase serves as a space for reflection that not only evaluates student learning outcomes,

but also assesses the quality, sustainability, and readiness of learning designs to continue to be developed.

Future Research Directions

Furthermore, the development of lecturer-oriented gamification research needs to be directed towards long-term testing to assess the stability, effectiveness, and sustainability of the model in higher education practice. It's important to understand not only whether gamification improves student engagement, but also how systematic design structures affect learning continuity, faculty workload balance, and the efficiency of the instructional process from semester to semester. In addition, technological developments such as generative AI open up new opportunities that are worth exploring in more depth, especially in supporting adaptive learning orchestration and more personalized feedback. Cross-testing across different STEM disciplines is also necessary so that the model is not only relevant in one particular context but has a wider cruising power. A mixed-method approach can provide a richer understanding of how lecturers make design decisions and manage cognitive load during the design process. With this direction of development, the Lecturer-Centered Gamification (LCG) model has the potential to develop into a pedagogical innovation framework that is not only conceptual, but also measurable, applicative, and systematically scalable.

5. Conclusions

Based on the PRISMA flow, this study screened 1,321 initial recordings to produce 97 articles that were fully assessed, and in the end only 11 studies met all the inclusion criteria. A total of 12 studies were issued because they focused on the K-12 context, 44 studies did not contain the dimension of the role of lecturers, and the other 30 studies did not have adequate pedagogical depth. This significant shrinkage suggests that gamification research that truly places lecturers as instructional designers is still very limited in STEM literature.

These findings are in line with the results of bibliometric analysis which show the dominance of themes such as gamification, students, and game-based learning, while the concept of instructional design and the role of lecturers are still not the focus. The thematic structure and keyword network suggest that literature is still driven by student orientation and technological innovation, rather than by a systematic pedagogical architecture. This condition confirms the conceptual gap that underlies the development of the Lecturer-Centered Gamification (LCG) model. By placing instructional design at the core, LCG offers a shift towards more structured, sustainable, and pedagogical quality-oriented gamification practices in STEM-based higher education.

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