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Exploring Concepts, Cutting-Edge Technologies, Best Practices, and Implications of Gamification Pedagogy in Education 4.0 (IR4.0): A Systematic Literature Review

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Abstract: *This systematic review discusses the pedagogy approach that has been integrated by teachers in sustaining the education curriculum in the era of the Fourth Industrial Revolution (IR 4.0). In defining the qualities required by 21st-century society, educators need to master the subject, be skilled in pedagogy, understand student development, comprehend learning psychology, utilize cutting-edge technology, filter research findings, planning the learning and facilitation process (PdPc), managing assessments, building networks, and applying leadership style. The advancement of new technologies within the National Policy on the Fourth Industrial Revolution (4IR) has widened the gap between the physical, digital, and biological realms (Ministry of Education, 2023), thereby necessitating the establishment of the Education 4.0 Framework. The formation of the National Policy on the Fourth Industrial Revolution (4IR) and the Education 4.0 Framework has outlined the need for teachers to implement innovative, proactive, and engaging pedagogical approaches, such as gamification pedagogy. Despite numerous studies on best practices in gamification education, there remains a gap in systematic literature reviews focused on the era of the Fourth Industrial Revolution (IR 4.0). The PRISMA method (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was used to analyze articles from databases such as SCOPUS, HRMARS, ERIC, and WoS. A comprehensive search of electronic databases using keywords and search strings yielded 190 publications from 2021 to 2024, all written in English, with only 16 articles selected based on predefined criteria. The outcome of this systematic review is expected to provide future researchers with direction to further explore other possibilities of gamification pedagogy approaches to ensure all students acquire knowledge and skills comprehensively.*

Keywords: The Fourth Industrial Revolution (IR 4.0), Gamification Pedagogy, Teaching and Learning (PdPc), Gamification Pedagogical Approaches and Teaching Methods

1. Introduction

The implementation of the education curriculum in Malaysia is based on the formulation of the national agenda by the Malaysian government, such as the Education 4.0 Framework, Developing a MADANI Nation, the Twelfth Malaysia Plan (RMKe-12), the Malaysia Digital Economy Blueprint (MyDIGITAL), the National Policy on the Fourth Industrial Revolution (4IR), Jalinan Digital Negara (JENDELA), the Malaysia Education Blueprint (PPPM) 2013–2025, and the National Science, Technology, and Innovation Policy (DSTIN) 2021–2030. Advances in new technologies within 4IR have increased the gap between the physical, digital,

and biological realms (Ministry of Education, 2023). Despite an increasing number of publications related to gamification pedagogy, there is a need for systematic studies specifically focused on the Fourth Industrial Revolution (IR 4.0). Several studies on gamification in education are theoretical and conceptual (Kim Hua Tan, Poh Phui Chan & Nur-Ehsan, 2021; MD Asadullah, Minara Yeasmin et. al., 2023). However, empirical research examining the actual implications or impacts of gamification pedagogy on learning outcomes and classroom management remains limited. Additionally, existing studies often do not use consistent and standardized measurement tools to assess the effectiveness of gamification in education. This inconsistency makes it difficult for researchers to compare study results and understand the true impact of gamification on student learning. The review by Veronica Basilotta, Maria Matarranz, Luis-Alberto, & Ana Otto (2022) details that although there has been an increase in research on teachers' digital competencies, further studies are needed to understand how gamification can be more effectively integrated into the education curriculum. Furthermore, comprehensive guidelines for implementing gamification pedagogical approaches are insufficient. To address this gap, this study focuses on a systematic literature review (SLR) to identify the concept, types of technology, best educational practices, and implications of IR 4.0 gamification pedagogical approaches used by educators to facilitate teaching and learning processes in the classroom.

The policy of the Fourth Industrial Revolution (4IR) and the Education 4.0 framework influence the selection and adaptation of educational pedagogies in the classroom. In defining the qualities required by 21st-century society, there is an enhancement of gamification pedagogical approaches for educational curriculum in the era of the Fourth Industrial Revolution (IR4.0). The production of this systematic review aims to contribute proposals regarding gamification pedagogical approaches that meet the criteria of the Fourth Industrial Revolution (4IR), enhance best educational practices, specify implications, and close the gap in educational curricula. Bibliometric analysis will indicate the number of citations for selected article publications based on sources, author names, research centers, research fields, and keywords. There are three main objectives of this systematic literature review:

1) Identifying the concept of gamification pedagogy for Educational Curricula in the era of the Fourth Industrial Revolution (IR4.0).
2) Identifying the types of technology used to implement PdPc processes in the era of the Fourth Industrial Revolution (IR4.0).
3) Identifying best practices of gamification teaching used to implement PdPc processes in the era of the Fourth Industrial Revolution (IR4.0).
4) Identifying the implications of gamification pedagogy for Educational Curricula in the era of the Fourth Industrial Revolution (IR4.0).

This systematic literature review aims to fill information gaps through a scoped review to provide answers and insights into the following questions:

1) What is the concept of gamification pedagogy in implementing PdPc processes in the era of the Fourth Industrial Revolution (IR4.0)?
2) What types of technology are used to implement PdPc processes in the era of the Fourth Industrial Revolution (IR4.0)?
3) What are the best practices of gamification pedagogy used to implement PdPc processes in the era of the Fourth Industrial Revolution (IR4.0)?
4) What are the implications of gamification pedagogy in implementing PdPc processes in the era of the Fourth Industrial Revolution (IR4.0)?

2. Methodology

This systematic literature review was conducted using the method by Munn et al. (2018) and the PRISMA 2020 statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [Page et al., 2021]. The PRISMA method involves three phases: (i) identification, (ii) screening, and (iii) inclusion of articles. Researchers initiated the analysis process by formulating research questions and conducting searches for articles related to gamification pedagogy for educational curricula in the Fourth Industrial Revolution (IR4.0) era.

2.1 Article Search Strategy

The SCOPUS database (a comprehensive high-impact database), HRMARS (Human Resource Management Academic Research Society), ERIC (Education Resources Information Center), specializing in gathering research and information in the field of education, and WoS (Web of Science) were used as the primary databases for article searches.

Table 1: Keywords and Databases Used in the Article Search

Database	Keywords	Identification Phase	Inclusion Phase
SCOPUS	((TITLE-ABS-KEY(fourth AND industrial AND revolution) AND TITLE-ABS-KEY(gamification)) .	19	9
HRMARS	“gamification” OR “Fourth Industrial Revolution”	27	2
ERIC	“gamification” OR “gamification pedagogy”	51	3
WoS	“gamification pedagogy” OR “fourth industrial revolution” OR “4IR”.	93	2
	Jumlah artikel kajian	190	16

Table 2: Criteria for Eligibility and Exclusion of Research Articles

Criteria for Selecting Research Articles	Eligibility	Exclusion
Year of Publication	2020 – 2024	2019 and research articles published before 2019.
Language of Study	English	Non-English
Study Design / Literature Type	Journal	Theses, proceedings, conferences, books, notes, and editorials.
Field of Study	Gamification in Educational Curriculum	Gamification other than in Educational Curriculum.

2.2 Article Selection Process and Research Issues

A total of 190 research articles were obtained using keywords through the SCOPUS, HRMARS, ERIC, and WoS databases. Researchers filtered articles that included keywords "gamification pedagogy" and "IR4.0" to provide an overall picture of educational research aligned with the Fourth Industrial Revolution (IR4.0). These articles were screened based on exclusion criteria: i) articles published before 2020, ii) non-English articles, iii) theses, proceedings, conferences, books, notes, and editorials, and iv) fields of study other than gamification in educational curriculum. This screening phase reduced the number of research articles to 50. Subsequent screening phases excluded articles lacking open access (n=17), full-text availability (n=8), and articles that did not meet the contextual criteria of the study (n=9). A total of 16 types of research articles were selected for this systematic literature review.

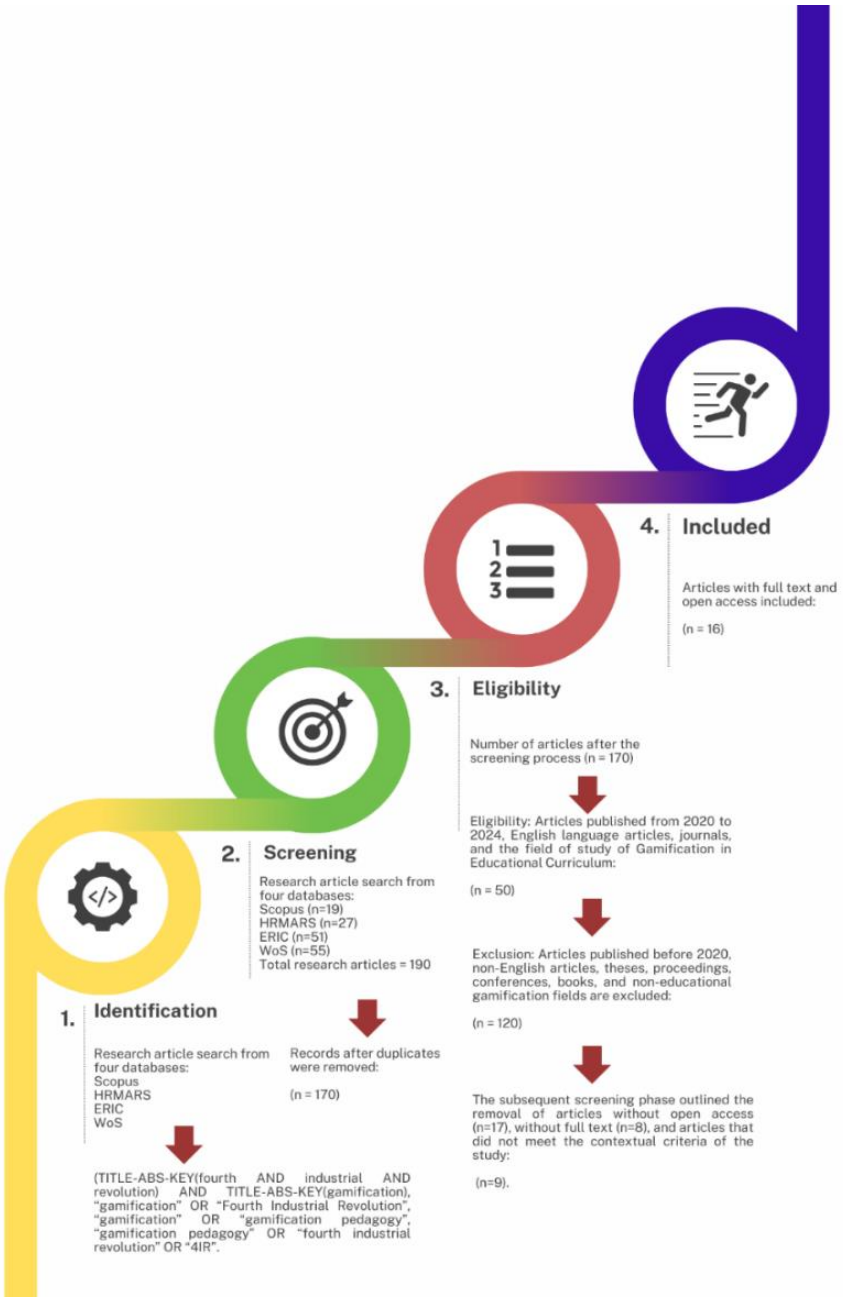

Figure 1: Article Selection Flow Using the PRISMA 2020 Protocol, Adapted from the Method by Munn Et Al. (2018) and the PRISMA 2020 Statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [Page et al., 2021]

2.3 Data Collection and Analysis

Relevant data, including titles, researchers' names, year of publication, and gamification pedagogy approaches used in each study, were extracted and systematically organized into tables to facilitate synthesis (using thematic analysis). Based on the table of data collection and analysis from 2020 to 2024, the types of IR4.0 gamification pedagogy approaches include mobile applications, project-based learning, flipped classrooms, augmented reality (AR), and virtual reality (VR). Four studies used a qualitative design (QL), namely A1, A4, A8, and A16. There was only one quantitative (QN) study, which is A10. The majority of articles used mixed methods (MM), including A2, A3, A5, A6, A7, A9, A11, A12, A13, A14, and A15. This mixed methods approach reflects the use of both quantitative and qualitative methods to obtain a comprehensive understanding of the research topic.

These articles were published between 2020 and 2024. One article was published in 2020 (A9). In 2022, five articles were published (A6, A7, A8, A10, A14), and there was a significant increase in 2023, with seven articles published (A3, A4, A5, A12, A13, A15, A16). In 2024, three articles were published (A1, A2, A11). The increasing number of publications each year reflects the rapid development in this field and the growing interest among researchers to explore and apply gamification and technology in education. The research topics studied are diverse, including language learning (A1), critical thinking and student self-confidence (A2), flipped classrooms and gamification (A3, A7, A15), digital game-based learning (A4, A5), project-based learning (A8), interactive geovisualization (A9), gamification in mathematics (A10), station rotation and gamification (A11), augmented reality (A12, A13), virtual reality (A14), and e-learning and MOOC (A16). By identifying patterns, trends, and gaps in the literature, this study lays a solid foundation for future research to enhance the effectiveness of learning and facilitation processes (PdPc) using modern technology.

Table 3: List of Research Articles

Number of Research Articles	Authors and Country	Year of Publication	Study Design	Article Title
A1	Mohamed Essafi, Latifa Belfakir & Mohammed Moubtassime. Morocco.	2024	QL	Investigating Mobile-Assisted Language Learning Apps: Babbel, Memrise, and Duolingo as a Case Study
A2	Atchanaphong Supnoon & Ratchanikorn Chonchaiya. Thailand	2024	MM	A study on the development of eleventh grade students' critical thinking skills and self-efficacy using active learning pedagogy with gamification.
A3	Usman Durrani, Mohammed Saleh, Rula Azzawi, Osama Hosam, Rasha Abousamra & Samer Aoudi. Dubai, United Arab Emirates.	2023	MM	Revolutionizing Higher Education: Enhancing Student Learning with CrossQuestion's Gamified Flipped Classroom Approach.
A4	Muhammad Nadeem, Melinda Oroszlanyova & Wael Farag. Kuwait.	2023	QL	Effect of Digital Game-Based Learning on Student Engagement and Motivation.
A5	Iñigo Aldalur & Alain Perez. Spain	2023	MM	Gamification and discovery learning: Motivating and involving students in the learning process
A6	Yunifa Miftachul Arif & Hani Nurhayati1 Indonesia	2022	MM	Learning Material Selection for Metaverse-Based Mathematics Pedagogy Media Using Multi-Criteria Recommender System
A7	Lui-Kwan Ng & Chung-Kwan Lo. China	2022	MM	Flipped Classroom and Gamification Approach: Its Impact on Performance and Academic Commitment on Sustainable Learning in Education.
A8	Xiongwei Lin, Hengli Liu, Qinbo Sun, Xiuhan Li, Huihuan Qian, Zhenglong Sun & Tin Lun Lam. China	2022	QL	Applying project-based learning in artificial intelligence and marine discipline: An evaluation study on a robotic sailboat platform.
A9	Ryan Heintzman. USA	2020	MM	Interactive Geovisualizations (iGEO): A New Approach to Teaching and Learning Physical Geography
A10	Boon Poh Ching & Nurfaradilla Nasri Malaysia	2022	QN	Quizizz-Based Gamification to Improve Fractions to Percentages Converting Ability among 5th Grade Students in SJKC Chong Cheng
A11	Azlinda Shafie Malaysia	2024	MM	Station Rotation Gamification in Education to Increase Students' Engagement Levels
A12	Seçil ÖZEREN & Ercan TOP.	2023	MM	The effects of Augmented Reality applications on the academic achievement and motivation of secondary school students
A13	Anggi Datiatur Rahmat, Heru Kuswanto, Insih Wilujeng & Riki Perdana. Indonesia	2023	MM	Implementation of mobile augmented reality on physics learning in junior high school students
A14	Almer Gungor, Denise Kool, May Lee, Lucy Avraamidou, Niek Eisink, Bauke Albada, Koos van der Kolk, Moniek Tromp & Johannes Hendrik Bitter. Netherlands.	2022	MM	The Use of Virtual Reality in A Chemistry Lab and Its Impact on Students' Self-Efficacy, Interest, Self-Concept and Laboratory Anxiety.
A15	Anas Jebreen, Abdelhafez Qasem & Fayez Saleem. Jordan	2023	MM	Students' Achievement in a Flipped Database Management Course: The Impact Of Flow Theory Gamification Elements.
A16	Younes-Aziz Bachiri, Hicham Mouncif & Belaid Bouikhalene Morocco.	2023	QL	Artificial Intelligence Empowers Gamification: Optimizing Student Engagement and Learning Outcomes in E-learning and MOOCs

(QN = Quantitative; QL = Qualitative; MM = Mixed Methods Quantitative-Qualitative).

3. Research Findings

Based on the four phases of article selection in this systematic literature review, 16 articles were identified that met the main objectives of the study. The strategic integration of technology-driven, game-based learning methodologies into the curriculum not only enhances student motivation and learning outcomes but also equips students with the competencies and adaptability required to navigate the complexities of the Fourth Industrial Revolution. This reinforces gamification as a catalyst for cultivating an agile and future-oriented educational framework.

Table 4: Findings of the Study, According to Detailed Themes

Number of Research Articles	Article Title	Type of Technology Used to Implement the PdPc Process.	Best Practices in Gamification Teaching	Implications of Gamification Pedagogy
A1	Investigating Mobile-Assisted Language Learning Apps: Babbel, Memrise, and Duolingo as a Case Study	MALL Apps	• Incorporating game elements: such as reward points, badges, levels, and leaderboards. • Tailoring gamified activities to individual needs. Providing opportunities for reflection and metacognition.	• Enhanced knowledge retention and transfer: through elements such as immediate feedback and meaningful rewards. • Development of 21st-century skills: such as critical thinking, problem-solving, collaboration, and communication.
A2	A study on the development of eleventh grade students' critical thinking skills and self-efficacy using active learning pedagogy with gamification.	Zoom: (Video conferencing platform) Kahoot!: Vonder Go: A virtual classroom platform.	• Enhancing Students' Intrinsic Motivation using reward systems, virtual currency, and challenging assignments. • Creating a Safe Environment for critical thinking and the development of higher-order thinking skills.	• Enhancing Thinking Skills, Critical Thinking, and Self-Efficacy. • Empowering Competencies Needed for the 21st Century. • Building Sub-Critical Skills, such as recognizing assumptions, evaluating arguments, drawing conclusions, and assessing arguments.
A3	Revolutionizing Higher Education: Enhancing Student Learning with CrossQuestion's Gamified Flipped Classroom Approach.	CrossQuestion's Gamified Flipped Classroom.	• Design Gamification Activities that promote critical thinking, problem-solving, and collaboration. • Use Elements such as Points, Badges, and Leaderboards as incentives for learning.	• Provide opportunities for students to interact with teachers and peers, enhancing learning outcomes. • Promote higher-order thinking skills and the application of knowledge and skills in real-world situations. • Gamification can be customized to different subjects and learning contexts to enhance student learning and achievement.
A4	Effect of Digital Game-Based Learning on Student Engagement and Motivation.	Augmented Reality (AR) Artificial Intelligence (AI) Chatbots	• Offering rewards and recognition. • Analyzing factors such as cost and readiness. • Empowering students with ownership and control.	• Increasing motivation and active engagement • Enhancing learning outcomes • Developing 21st-century skills • Improving social interaction.
A5	Gamification and Discovery Learning: Motivating and Involving Students in The Learning Process.	The WebQuests	• Designing gamification activities tailored to the needs and characteristics of students • Utilizing game-based mechanics, aesthetics, and game-thinking to engage students and promote learning.	• Enhancing student motivation and engagement in the learning process. • Improving student attention and focus during subject theory teaching. • Enhancing information searching and research skills to solve problems.

A6	Learning Material Selection for Metaverse-Based Mathematics Pedagogy Media Using Multi-Criteria Recommender System.	Metaverse Technology Virtual Reality (VR) Unity Game Engine: An MMPM system built using the Unity game engine.	• Multimedia Technology Utilization. • Subject Matter Visualization: 3D visualization through VR-based metaverse systems.	• Personalized Learning: It provides a more interactive and immersive learning experience. The LMS system proposed in the study uses the MCRS method to adaptively select subject materials based on students' knowledge levels. This personalized learning approach ensures students receive learning materials suited to their understanding level, enhancing learning efficiency.
A7	Flipped Classroom and Gamification Approach: Its Impact on Performance and Academic Commitment on Sustainable Learning in Education.	Gamified Flipped Classroom.	• Using game design elements such as points, badges, and leaderboards to encourage student engagement and motivation. Providing recognition and rewards through badges. • Aligned with learning objectives by focusing on solving real business problems and simulations.	• Enhancement of student engagement and motivation. • Encouraging active learning. • Promoting collaboration and teamwork. • Enhancing problem-solving skills.
A8	Applying project-based learning in artificial intelligence and marine discipline: An evaluation study on a robotic sailboat platform.	Electronic components (Arduino Nano, servo, Bluetooth, IMU). PID control. Computer vision	• Practical operations: conducting practical operations where students can apply their knowledge in real-life situations. • Games: as a tool to teach and reinforce learning concepts.	• Developing 21st-century literacy skills: fostering critical thinking, problem-solving, and collaboration skills crucial for the 21st century. • Bridging disciplinary gaps in education: gamification can help bridge disciplinary gaps in education, providing a more holistic and integrative approach to learning.
A9	Interactive Geovisualizations (iGEO): A New Approach to Teaching and Learning Physical Geography	Interactive Geovisualization (iGEO). Virtual Field Work Tools.	• Providing Meaningful Learning Experiences: Testing students' mental abilities, enabling collaboration or interaction with others through roles, and providing entertainment and healthy challenges in the learning journey.	• Increased Student Motivation: • Exploration of Diverse Gamification Techniques: • Integration with Pedagogical Approaches: • A more integrated and effective learning experience for students.
A10	Quizizz-Based Gamification to Improve Fractions to Percentages Converting Ability among 5th Grade	Quizizz application: Using a computer, tablet, or smartphone.	• Clear learning objectives setting. • Challenge orientation and game elements.	• Positive impact on students' achievement levels in converting fractions to percentages and vice versa. • Interactive and engaging learning experience for students, motivating them to learn.

	Students in SJKC Chong Cheng			• Assisting in addressing challenges students face in understanding and solving problems involving percentages.
A11	Station Rotation Gamification in Education to Increase Students' Engagement Levels	Station rotation gamification.	• Creating an Enjoyable Learning Environment: Foster an environment that promotes fun and excitement in learning.	• Enhanced Student Engagement and Motivation. • Effective Problem-Solving Rates.
A12	The effects of Augmented Reality applications on the academic achievement and motivation of secondary school students	Augmented Reality (AR) Application.	• Providing clear goals and objectives: Helping students understand what needs to be achieved, providing direction and purpose. • Tailoring to individual needs and preferences.	• Increased motivation. • Enhanced learning outcomes: through interactive and immersive learning experiences. • Improving understanding, content retention, problem-solving skills, and critical thinking. • Encouraging active participation, fostering enjoyment in the learning process.
A13	Implementation of mobile augmented reality on physics learning in junior high school students	Augmented Reality (AR) Virtual Reality (VR) Holographic display technology.	• Clear goals and objectives • Meaningful rewards and feedback • Collaboration and competition • Tailoring learning experiences according to individual needs and preferences.	• Increased motivation and engagement. • Improvement in learning outcomes. • Enhancement of problem-solving skills and critical thinking. • Increased collaboration and social interaction: working together, sharing knowledge, and supporting each other's learning.
A14	The Use of Virtual Reality in A Chemistry Lab and Its Impact on Students' Self-Efficacy, Interest, Self-Concept and Laboratory Anxiety.	Headsets Controllers: Sensors and Trackers: Haptic Feedback Devices: Mobile VR: Room-scale VR Software. 360-Degree Cameras.	• Align VR experiences with learning objectives. • Provide clear instructions and guidance before starting the VR experience. • Integrate VR with different teaching methods: VR as a supplement to other teaching methods to enrich the learning experience.	• Enhancing Student Understanding through deep and realistic learning experiences. • Experiential and Situated Learning: Helping students grasp concepts in contextualized settings. • Development of Critical Thinking and Problem-Solving Skills: Through simulations of real-world scenarios. • Accessibility and Inclusivity: VR provides tailored learning experiences for students with diverse needs.
A15	Students' Achievement in a Flipped Database Management Course:	Gamified Flipped Classroom. Tools like Quizizz, Kahoot, and Quizalize.	• Using gamified quizzes as activities in class.	• Highest impact on student achievement, surpassing other teaching methods. • Improvement in overall achievement and grades.

	The Impact Of Flow Theory Gamification Elements.		• Providing feedback at the assignment level by awarding points for correct answers in gamified quizzes. • Allowing additional opportunities to earn more points through 'power-ups'.	
A16	Artificial Intelligence Empowers Gamification: Optimizing Student Engagement and Learning Outcomes in E-learning and MOOCs	Artificial Intelligence (AI) Processing (NLP Moodle Plugin: Automatic Question Generation	• Incorporating Game Design Elements: points, badges, levels, rewards, and achievements into learning activities and assessments. • Integrating pedagogical learning with Learning Management Systems (LMS): Using tools like Moodle plugins such as QuizVentor. This tool provides game-based quiz templates, allows adjustment of game parameters (e.g., time limits, scoring systems), and offers a dashboard interface for tracking student progress and achievements.	• Increased Motivation and Engagement: Gamification can create competition, enhance achievement, success, and encourage students to actively participate in the teaching and learning process. • Enhanced Learning Outcomes: Through AQG integrated with the Moodle plugin, it can boost motivation and improve learning outcomes. • Integration of Gamification and AI technologies, such as AQG and NLP, enables adaptive learning experiences. • Innovative Assessment Practices: Gamification in education, combined with AI technology, offers innovative assessment practices aligned with priorities, needs, and digital learning contexts.

4. Synthesis and Discussion

4.1 Concept of Gamification Pedagogy, to Implement the Teaching and Learning Process in The Era of the Fourth Industrial Revolution (IR4.0).

The concept of gamification pedagogy emerges as a multifaceted approach across educational research, as evidenced by findings from 16 diverse studies. Gamification, defined as the integration of game elements and mechanics into educational contexts, consistently demonstrates its ability to enhance student engagement, motivation, and learning outcomes. Mohamed Essafi et al. (2024) emphasize how gamification elements like leaderboards and rewards align with communicative language teaching, fostering interaction and engagement in language learning (A1). Atchanaphong Supnoon and Ratchanikorn Chonchaiya (2024) further highlight gamification's role in creating competitive, game-like environments that stimulate active student participation (A2). Usman Durrani et al. (2023) discuss the effective application of gamification in higher education through the CrossQuestion application, utilizing badges and leaderboards to motivate student learning and participation (A3). Muhammad Nadeem, Melinda Oroszlanyova, and Wael Farag (2023) reinforce these findings by illustrating how gamification principles such as points and challenges enhance the interactive and enjoyable aspects of learning (A4).

Innovative approaches like the metaverse-based mathematics pedagogy media (MMPM), as highlighted by Yunifa Miftachul Arif and Hani Nurhayati (2022), leverage gamification to create immersive learning experiences that adapt to students' knowledge levels (A6). Lui-Kwan Ng and Chung-Kwan Lo (2022) emphasize the psychological benefits of gamification, supporting students' autonomy and intrinsic motivation through choice and challenge (A7). Additionally, Xiongwei Lin et al. (2022) and Ryan Heintzman (2020) explore gamification's application in project-based and geography education, respectively, underscoring its effectiveness in enhancing engagement and understanding (A8, A9). Boon Poh Ching and Nurfaradilla Nasri (2022) discuss gamification's role in mathematics education, particularly in adapting to online learning environments during the COVID-19 pandemic, highlighting tools like Quizizz for effective implementation (A10). Azlinda Shafie (2024) further explores gamification through the Station Rotation Gamification (SRG) approach, emphasizing its positive impact on student achievement despite potential challenges (A11). Seçil Özeren and Ercan Top (2023) and Almer Gungor et al. (2022) explore gamification through augmented reality (AR) and virtual reality (VR), respectively, demonstrating how these technologies enhance engagement and self-efficacy (A12, A14). Anas Jebreen, Abdelhafez Qasem, and Fayez Saleem (2023) advocate for gamified flipped classrooms, showing improved academic performance through strategic gamification design (A15). Finally, Younes-Aziz Bachiri, Hicham Mouncif, and Belaid Bouikhalene (2023) highlight gamification's integration with artificial intelligence (AI), emphasizing personalized learning experiences that boost engagement and learning outcomes (A16).

In conclusion, the synthesis of these studies underscores gamification as a versatile and effective pedagogical strategy across various educational disciplines. By integrating game elements and mechanics, educators can create dynamic and engaging learning environments that cater to diverse student needs, enhance motivation, and improve overall academic achievement. As educational practices continue to evolve, gamification stands out as a pivotal tool for transforming traditional teaching methods and fostering meaningful learning experiences in the digital age.

4.2 Types of Technology Used to Implement Pdpc in the Era of The Fourth Industrial Revolution (IR4.0).

The government's commendable efforts in providing curriculum designs, infostructure, infrastructure, resource utilization, and educational development will not materialize without the involvement of human resources as education implementers, especially teachers facing the changes of the Fourth Industrial Revolution (IR4.0). In defining the demands of a quality society characteristic of the 21st century in the era of the Fourth Industrial Revolution (IR4.0), there are enhancements in learning approaches such as virtual immersion (e.g., VR/AR/Virtual Simulation/MOOCs/LMS), blended immersion (e.g., Blended Learning/Flipping the Classroom), and face-to-face immersion (e.g., Service-based Learning, Community-based Learning, Challenge-based Learning, Work-based Learning, Problem-based Learning) (KPM, 2019). The following includes graphical projections of the types of IR4.0 PDPc technology, findings from 16 research articles conducted by researchers:

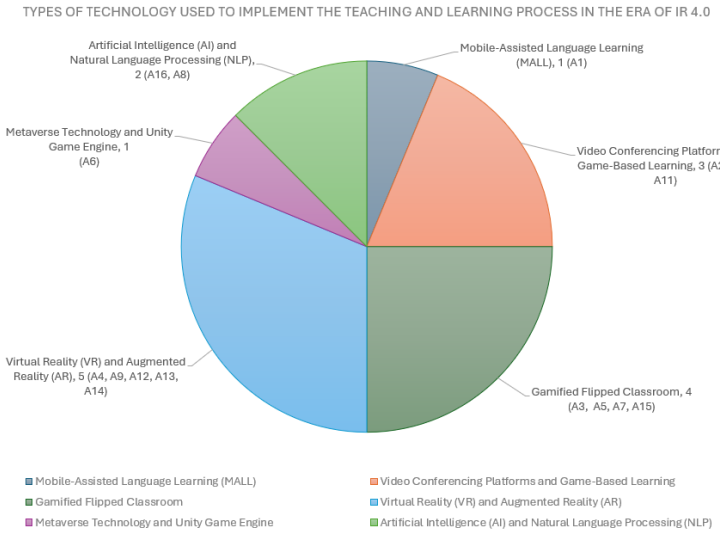

Figure 2: Technologies Used to Implement Teaching and Learning Processes in the Fourth Industrial Revolution (IR4.0).

4.3 Best Practices in Gamification Teaching Methods for Implementing PdPc Processes in the Era of the Fourth Industrial Revolution (IR4.0).

The development of student generations in the era of the Fourth Industrial Revolution (IR4.0) is influenced by digital culture and technology. The pedagogical skills framework is built on three core skills: learning and innovation skills, life and career skills, and information, media, and technology skills (Haliza Hamzah & Joy Nesamalar, 2016). The effectiveness of developing these skills depends on the best teaching practices implemented by teachers in the classroom. To enhance the learning process's effectiveness, teachers must practice setting detailed learning goals and objectives (Muhammad Nadeem, Melinda Oroszlanyova & Wael Farag, 2023). There is a need to plan various contingencies to prepare for potential constraints, such as technology malfunctions or teaching aid failures, without negatively impacting teaching. Seçil ÖZEREN & Ercan TOP (2023) stated that clear goal-setting helps students understand what needs to be achieved and provides direction and purpose. Feedback can solve problems and change students' thinking and behavior. The integration of game elements like reward points, badges, and leaderboards is an effective initiative for providing feedback on performance, views, and problems (Muhammad Nadeem, Melinda Oroszlanyova et al., 2023; Anas Jebreen, Abdelhafez Qasem & Fayez Saleem, 2023). Articles A5, A1, A12, and A13 highlight the need for teachers to personalize the learning experience according to individual needs. The adaptation of gamified pedagogy based on students' proficiency levels, abilities,

characteristics, preferences, and needs can enhance the understanding of subjects (Iñigo Aldalur & Alain Perez, 2023; Mohamed Essafi, Latifa Belfakir & Mohammed Moubtassime, 2024; Anggi Datiatur et al., 2023). An example of educational practice includes allowing students to choose avatars and set their own learning paths (Özeren & Ercan Top, 2023).

Teaching activities based on new IR4.0 technology or high difficulty levels require planned management patterns. Teachers, as implementers and monitors of education, need to provide optimal opportunities for students to take responsibility for self-learning through collaborative practices and healthy competition. Encouraging collaboration and competition in gamified activities can promote critical thinking, problem-solving, reflection, and discussion among students (Atchanaphong Supnoon & Ratchanikorn Chonchaiya, 2024; Muhammad Nadeem, Melinda Oroszlanyova & Wael Farag, 2023). These educational best practices can be achieved through challenging gamification assignments and group-based activities (Özeren & Ercan Top, 2023). Each student has different personality levels, temperaments, and needs. The diversity of students in the classroom has increased the risk of problematic behavior cases. Research by Dayang & Izwan (2021) showed that deviant peer involvement is a factor in delinquent behavior. Establishing routines through accurate instructions, planning, and gamified activity design can enhance active engagement, motivation, competitive interaction, and efficient time management (Anas Jebreen, Abdelhafez Qasem & Fayez Saleem, 2023; Azlinda Shafie, 2024; Almer Gungor et al., 2022). Findings from these 16 research articles show that using game elements, clear goal setting, immediate feedback, personalized learning experiences, collaboration and healthy competition, and classroom routine control through gamification can create a more effective and engaging learning environment, fostering the development of critical thinking and problem-solving skills among students.

4.4 Pedagogical Implications of Gamification for the Curriculum in the Era of the Fourth Industrial Revolution (IR4.0).

The Fourth Industrial Revolution (IR4.0) demands that teachers align education with advancements in technology, economy, and information acquisition. Educational focus needs to be infused with elements of learning and innovative skills, life and career skills, and information, media, and technology skills. Findings indicate uniformity and consensus in highlighting the positive implications of gamified pedagogy for IR4.0. Below is a graphical projection, synthesis, and discussion on the implications of gamified pedagogy for the curriculum in the era of the Fourth Industrial Revolution (IR4.0), based on findings from 16 research articles conducted by various researchers:

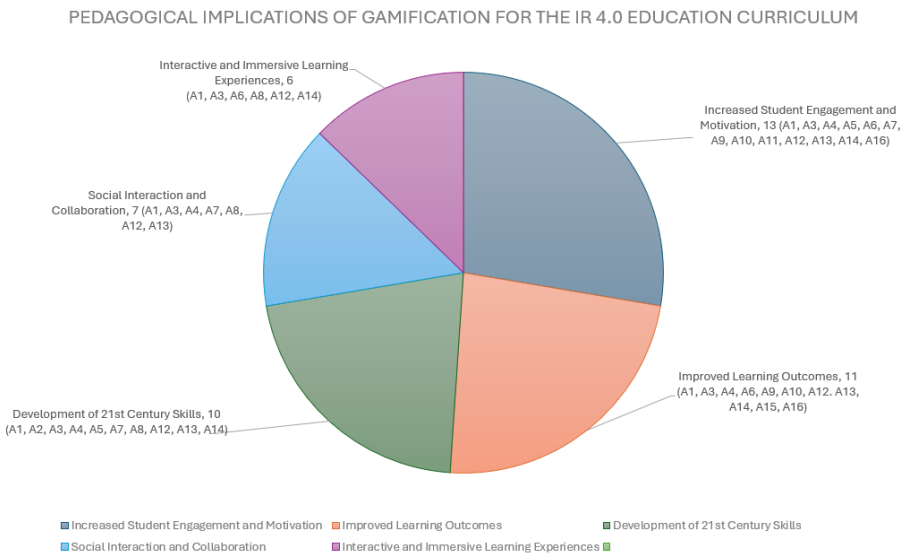

Figure 3: Pedagogical Implications of Gamification for the Curriculum in the Era of the Fourth Industrial Revolution (IR4.0).

The study by Mohamed Essafi et al. in Morocco (2024) and Anggi Datiatur Rahmat et al. in Indonesia (2023) shows that mobile applications and augmented reality (AR) have positively impacted enhancing language and physics learning among students. Applications like Babbel, Memrise, and Duolingo, as well as the use of augmented reality, provide interactive platforms that help students increase motivation and understand learning concepts. Student motivation and readiness levels are internal conditions involving cognitive skills, emotional stimulation, and physical abilities (Noriati A. Rashid, Boon Pong Ying & Sharifah Fakhirah, 2017). Motivation refers to the enthusiasm, attitude, curiosity, perseverance, interest, and value in engaging in learning. There are two types of learning motivation: (i) intrinsic motivation, driven by natural student inclinations, and (ii) extrinsic motivation, engineered by external factors such as rewards and penalties. Muhammad Nadeem et al. in Kuwait (2023) and Boon Poh Ching & Nurfaradilla Nasri in Malaysia (2022) highlight the effectiveness of gamification in enhancing active student engagement, such as through platforms like Quizizz, which improve students' ability to understand and convert fractions into percentages. Studies by Almer Gungor et al. in the Netherlands (2022) and Seçil ÖZEREN & Ercan TOP (2023) detail the use of virtual reality (VR) and augmented reality (AR) in chemistry labs and other subjects, which have boosted students' confidence, interest, and reduced anxiety. Integrating IR4.0 technologies provides a deep and interactive learning experience that traditional methods cannot achieve.

Research by Xiongwei Lin et al. in China (2022); Atchanaphong Supnoon & Ratchanikorn Chonchaiya in Thailand (2024); Azlinda Shafie in Malaysia (2024), and Usman Durrani et al. in the UAE (2023) focuses on project-based gamified learning approaches, student-centered learning, and flipped classrooms. These approaches empower critical and creative thinking and student efficacy in the classroom. The study by Yunifa Miftachul Arif & Hani Nurhayati in Indonesia (2022) shows that selecting appropriate learning materials based on the metaverse, applying multi-criteria decision-making systems, is crucial for ensuring the effectiveness of the learning process. This study indicates that innovations in education need to be tailored to industry needs and local contexts to achieve optimal learning outcomes. Overall, these studies show that the use of modern technology and innovative learning approaches can enhance the quality of learning and student engagement. Integrating technologies such as mobile applications, augmented reality, virtual reality, and active pedagogical approaches provides a

more meaningful, interactive, and engaging learning experience, ultimately improving academic performance and student motivation comprehensively.

5. Conclusion

This study is a systematic literature review that analyzes concept, technology, best educational practices, and the pedagogical implications of gamification in the era of the Fourth Industrial Revolution (IR4.0). Utilizing the PRISMA protocol, keywords such as "gamification," "gamification pedagogy," "Fourth Industrial Revolution," and "4IR" yielded 190 research articles from databases including SCOPUS, HRMARS, ERIC, and WoS. Bibliometric analysis indicated significant growth in published studies from 2020 to 2024. An analysis of 16 articles on technology, best educational practices, and the pedagogical implications of gamification in the IR4.0 era found that technologies such as artificial intelligence (AI), augmented reality (AR), metaverse technology, mobile-assisted learning, virtual reality (VR), and the Internet of Things (IoT) play crucial roles in driving Education 4.0.

Gamification pedagogy, as evidenced by the study of Mohamed Essafi et al. (2024), enhances student motivation and engagement through engaging and interactive learning experiences, supporting the development of 21st-century skills and social collaboration (Usman Durrani et al., 2023 and Iñigo Aldalur & Alain Perez, 2023). The strength of this study lies in its comprehensive review of specific themes that are rarely found in the literature. The gaps and limitations analyzed from the 16 studies include the lack of research on teachers' professional competencies, assessment of educational institutions' readiness, ethics (data security, algorithmic discrimination, digital inequality), and limited focus on higher education. This study also suggests further research in evaluating the effectiveness of active learning methodologies in IR4.0, analyzing the challenges of integrating technology, preparing schools to implement IR4.0 gamification pedagogy (based on infrastructure and competency levels), and addressing ethical violations and user safety. This research can assist future researchers in studying the development of Education 4.0, ethical issues, teacher training, and analyzing the impact of the Fourth Industrial Revolution (IR4.0) on school subjects. Teachers, as the implementers of learning, play a crucial role in educating and guiding students in line with the goals of the National Fourth Industrial Revolution Policy (4IR), the Education 4.0 Framework, and PPPM (2013-2025).

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