Chapter 3

Gamification Strategies in STEM Education

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Chapter Highlights

This chapter examines gamification as an instructional approach in STEM education, focusing on its potential to enhance student engagement, motivation, and learning outcomes. By drawing on theoretical frameworks and empirical findings, it explores how gamified learning environments can address diverse learner needs while also considering implementation challenges and future research directions.

- Role of Gamification in STEM – Examines how gamification enhances student engagement and learning outcomes across STEM disciplines.
- Theoretical Foundations – Discusses key frameworks such as intrinsic motivation theory and flow theory to explain the effectiveness of gamified learning.
- Instructional Strategies – Explores a range of gamification techniques applied in different STEM contexts and subject areas.
- Student Outcomes and Diversity – Analyzes the impact of gamified learning on students from diverse backgrounds, including motivation, achievement, and satisfaction.
- Challenges and Limitations – Identifies critical issues such as demographic differences, implementation difficulties, and limited long-term empirical evidence.

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Introduction

STEM education, which combines science, technology, engineering, and mathematics, is very important in helping students to develop skills of critical thinking, creativity, and solving problems. This kind of interdisciplinary approach prepares learners to face the fast changes of modern technology and society (Jindal et al., 2023). In current practice, STEM teaching often uses methods such as problem-based, inquiry-based, project-based, and cooperative learning. These strategies give students chance to work together on interdisciplinary tasks, so they can strengthen their ability in problem solving and critical thinking (Ravi et al., 2023). Recently, teachers also try to use more personalized methods, so that learning can be adjusted to the needs of each student and give better results (Bontchev et al., 2024). Gamification in the classroom means using game elements in situations outside of real games, with the purpose to increase motivation and engagement of students (Palomino et al., 2023; Vrcelj et al., 2023). It usually includes points, badges, leaderboards, and other rewards to make lessons more interactive and enjoyable (Al-Hafdi & Alhalafawy, 2024). This technique is useful especially for subjects that sometimes look difficult or boring, because it offers another way to attract student attention (De Sousa Borges et al., 2014). By making lessons more enjoyable, gamification can support students to achieve learning goals in more effective way (Feng et al., 2024).

One of the common problems in STEM education is low motivation and lack of interest from students. Gamification can help to solve this issue by creating learning activities that are more engaging and exciting (Dicheva et al., 2023). Studies also show that when digital rewards such as badges or points are used, students show better performance and interest in learning, for example in physics lessons (Andrade et al., 2020). At the same time, gamification helps students to adapt to new learning situations and reduce negative feeling about competition (Funa et al., 2021). However, it is necessary that gamification is designed carefully, so it can fit both individual and group learning processes (Borges et al., 2016). By using gamification in STEM education gives strong potential to improve student motivation and engagement. If teachers combine it with innovative teaching methods and personalized learning, the classroom can become more effective and also more enjoyable for students (Klock et al., 2018; Sawarkar et al., 2024).

Theoretical Foundations of Gamification in STEM Education

Gamification in STEM education is the use of game design elements to make students more engaged, motivated, and able to remember what they learn.

The main theories that explain gamification are Constructivism, Behaviorism, Self-Determination Theory (SDT), and Flow Theory. Constructivism says students learn better when they create knowledge from their own experience, and this matches with gamification because it is interactive in nature (Rukadikar & Khandelwal, 2025; Daungtod & Chaijareon, 2019). Behaviorism talks about reinforcement and conditioning, and in gamification this can be seen in the use of points or badges that reward positive actions (Landers et al., 2015). SDT focuses on the human need for competence, autonomy, and relation with others. In gamification, this theory is important because it gives internal motivation when students get choices and social connection (Schaper et al., 2022; Sangroya & Kabra, 2023). Flow Theory explains the condition where students are fully concentrated and enjoy the task, and gamification can create this situation when the task is difficult but still possible, and feedback is given quickly (Rukadikar & Khandelwal, 2025; Sangroya & Kabra, 2023).In STEM education, different game strategies are used such as points, leaderboards, badges, and storytelling. Points and leaderboards bring competition and feeling of success, which make students more motivated and active in learning (Chatzidaki et al., 2025; Jun & Lucas, 2025). Badges alone are not so strong, but when combined with other elements they make the gamified system more powerful (Chatzidaki et al., 2025). Storytelling elements, like the hero's journey, can create immersive and meaningful lessons, which help students connect to the topic and remember it longer (Sotirov et al., 2024). Studies also show these strategies improve academic results and keep motivation longer in gamified learning environments (Jun & Lucas, 2025; Jaskari & Syrjälä, 2024)

Even so, gamification in STEM education must be designed with care. It needs to match the goals of the lesson and take into account the different needs of students. A good gamification design should not only give external rewards, but also increase internal motivation, so students do not depend only on surface incentives (Jaskari & Syrjälä, 2024; Leong, 2025). The design should give clear challenges, fast feedback, and support the psychological needs of learners, so they stay engaged and go deeper in their learning (Sangroya & Kabra, 2023). It is also important to review and improve gamified strategies from time to time, so they continue to fit the changes in student needs and bring maximum benefit in education (Chatzidaki et al., 2025; Leong, 2025).In conclusion, gamification in STEM education is supported by strong learning theories, and it uses points, leaderboards, badges, and narratives to make learning more engaging and effective. But its success depends on careful design and continuous adjustment, so that it can achieve the learning goals and also answer the diverse needs of students.

Table 1. Summary table of Theoretical Foundations of Gamification

Aspect	Findings	Sources
Theoretical Foundations	Constructivism: Active learning through experiences	(Rukadikar & Khandelwal, 2025), (Daungtod & Chaijareon, 2019)
	Behaviourism: Reinforcement through rewards (points, badges	(Landers et al., 2015), (Banerjee et al., 2024)
	Self-Determination Theory (SDT): Competence, autonomy, relatedness	(Schaper et al., 2022),(Sangroya & Kabra, 2023)
	Flow Theory: Deep immersion through challenging tasks and feedback	(Sangroya & Kabra, 2023) (Rukadikar & Khandelwal, 2025),
Game Strategies	Points and Leaderboards: Competition and achievement	(Chatzidaki et al., 2025), (Jun & Lucas, 2025)
	Badges: Supplementary motivation	(Banerjee et al., 2024), (Chatzidaki et al., 2025)
	Narrative Elements: Immersive learning paths	(Velazquez-Garcia et al., 2025)
Design	Alignment with Objectives: Tailored to instructional goals	(Jaskari & Syrjälä, 2024), (Leong, 2025)

Key Gamification Strategies for STEM Learning

Game-based Learning and Gamification as Two Concepts

Game-based learning (GBL) and gamification are two different but related methods in education. GBL uses real games as a tool to support learning, taking advantage of the fun and interactive nature of games to teach certain knowledge or skills. On the other hand, gamification does not use full games but brings game elements like points, badges, or leaderboards into normal learning to make students more motivated and engaged (Studart, 2022; Chung et al., 2025; Dahalan et al., 2024). The main difference is that GBL focuses on games themselves as the learning medium, while gamification applies game mechanics inside traditional lessons to create more attractive experience.Research shows that both methods give positive impact on student motivation, participation, and learning outcomes (Chung et al., 2025; Zabala-Vargas et al., 2021; Vasbieva & Kalugina, 2024). For example, GBL has been used in engineering education to help students understand and remember difficult concepts more effectively (Zabala-Vargas et al., 2021). At the same time, gamification has been proven useful for improving motivation and interest in many contexts, such as language classes and vocational training (Dahalan et al., 2024; Vasbieva & Kalugina, 2024).

Use of Points, Badges, and Leaderboards (PBL) as Motivational Tools for Students

Points, badges, and leaderboards (PBL) are the most common elements used in gamification for education. These features act as external motivators, giving students quick feedback and recognition for what they achieve (Daud et al., 2017; Denden et al., 2020; Badea & Popescu, 2024). Points are usually given when students finish tasks or reach certain goals. Badges work as visual symbols to show accomplishments, while leaderboards arrange students according to performance, creating competition (Daud et al., 2017; Denden et al., 2020). Many studies report that PBL can increase student motivation and participation because it makes the classroom more competitive and rewarding (Daud et al., 2017; Denden et al., 2020; Badea & Popescu, 2024).Still, the impact of these elements is not the same for every student or learning context. Some learners enjoy competition and do better with leaderboards, but others may lose interest if they always stay at the bottom rank (Daud et al., 2017). Because of this, teachers need to design and balance PBL carefully so it can suit the different needs and preferences of students (Daud et al., 2017; Denden et al., 2020).

Role-playing and Simulation, with Advanced Techniques of Immersive Gamification

Role-playing and simulation are higher-level gamification methods that give students immersive and interactive learning experience. With these approaches, learners can take part in realistic situations, practice important skills, and get feedback directly, which helps them to learn better and remember longer (Otemaier et al., 2024; Teerawongpairoj et al., 2024; Li & Edwards, 2020). In STEM education, role-playing games (RPGs) and simulations are very useful because applying theory into practice is a key part of the learning process (Otemaier et al., 2024; Teerawongpairoj et al., 2024).For example, role-playing has been used with software engineering students to train them in requirement elicitation interviews, and this activity improved both engagement and performance (Otemaier et al., 2024). In the same way, gamified simulations in virtual reality (VR) give safe and controlled environments for students to practice complex skills, and this improves motivation and learning results (Kwok et al., 2023).These advanced gamification techniques not only make the lesson more interesting, but also help students to build skills in critical thinking, problem solving, and teamwork (Otemaier et al., 2024; Teerawongpairoj et al., 2024; Kwok et al., 2023).

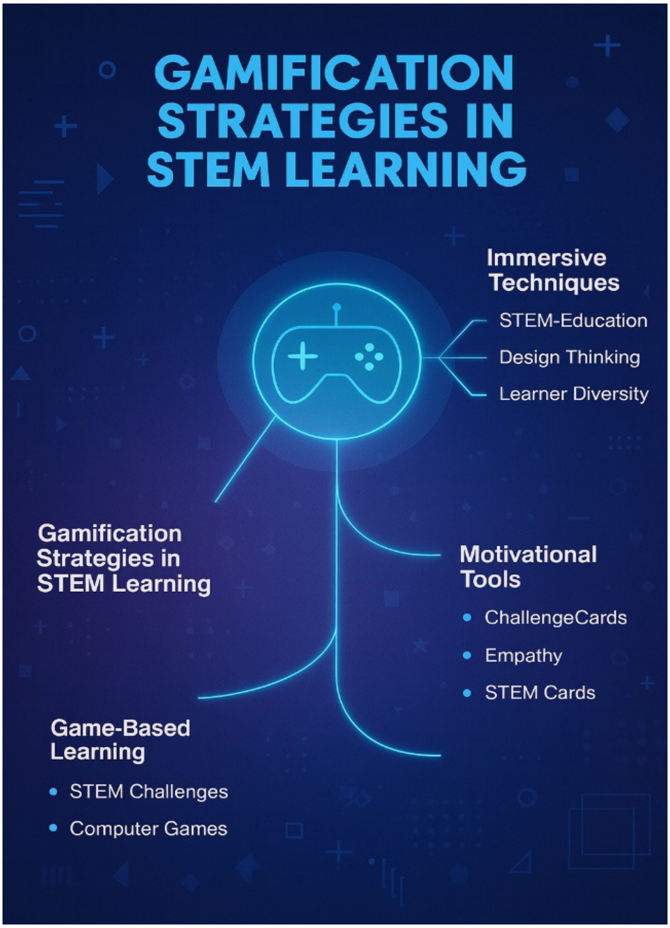

Figure 1. Gamification Strategies in STEM Learning

In conclusion, both game-based learning (GBL) and gamification are useful methods to improve STEM education. GBL uses the learning power of games directly, while gamification brings game mechanics into normal classroom to increase student interest and motivation. Using points, badges, and leaderboards can encourage learners, but the design must think about different student needs. More advanced methods such as role-playing and simulation give immersive learning that improve practical skills and engagement, which is very important in STEM field. With more studies in the future, these approaches show strong potential to build learning that is more attractive and more effective.

Technological Tools and Platforms for Gamified STEM Education

STEM-focused educational games and interactive simulation exercises (Minecraft: Education Edition, Kahoot!).

The use of technology tools and platforms in gamified STEM education shows strong potential to improve student engagement, motivation, and learning results. Two popular examples are Minecraft: Education Edition and Kahoot!, which are often used as STEM games and interactive activities. Minecraft: Education Edition, built from the famous game Minecraft, is applied in classrooms to create immersive and metaverse-like learning spaces. Studies show it helps students to feel social presence, empathy, and active participation, especially in subjects such as Chemistry, Coding, and AI (Singh & Sun, 2025). Its success also comes from creating immersion with challenge, flow, and competence (Singh & Sun, 2025). Another strength of Minecraft is supporting collaboration, because students can work together on tasks, which leads to better academic results and stronger inner motivation (Zheng & Wang, 2023).

Kahoot! is different, as it is mainly a gamified quiz platform where teachers prepare and run quizzes in a playful style. Research shows Kahoot! has positive impact on engagement, motivation, and understanding of lessons (Balaskas et al., 2023; López et al., 2022). For example, in a study with Grade 6 students, adding Kahoot! to normal teaching increased interest, enjoyment, and sense of autonomy (Balaskas et al., 2023). In higher education, students who used Kahoot! quizzes also achieved better results than those who did not, but researchers note the tool alone cannot guarantee success (López et al., 2022). The platform works well because it creates a creative and supportive learning environment, which encourages students to participate actively (Balaskas et al., 2023). Overall, both Minecraft: Education Edition and Kahoot! show the power of gamified tools in changing STEM education into more interactive, engaging, and effective learning. In conclusion, using these tools in STEM classrooms has been proven to improve student motivation, engagement, and outcomes. They apply gamification principles to design immersive experiences that make difficult STEM concepts easier and more enjoyable. As technology keeps developing, such tools will become even more important for the future of STEM education.

Table 2. Educational Tools in STEM Gamification: Features, Impacts, and Empirical Findings

Tool	Key Features	Educational Impact	Study Findings
Minecraft: Education Edition	Metaverse-like environment Collaborative tasks - Immersive learning	Enhances social presence Fosters empathetic engagement Promotes behavioral involvement	Significant contribution to immersion through competence, flow, and challenge (Singh & Sun, 2025) Improved academic performance and intrinsic motivation through collaborative learning (Zheng & Wang, 2023) Positive impact on interest, enjoyment, and autonomy (Balaskas et al., 2023)
Kahoot!	Gamifiedquizzes Mobile-friendly Real-time feedback	Increases student engagement Enhances motivation and understanding Encourages autonomous learning	Better academic performance in higher education (López et al., 2022)

Application of virtual and augmented reality (VR/AR) in teaching STEM disciplines.

The use of Virtual Reality (VR) and Augmented Reality (AR) in STEM teaching has become more popular in recent years because of their ability to give immersive and interactive learning experience. These technologies can increase student engagement, motivation, and understanding of difficult concepts by offering dynamic and real-time interaction with virtual objects (Guerra et al., 2024; Giang et al., 2025; Al-Azawi et al., 2019; Kononov et al., 2025). For example, AR and VR can change abstract STEM ideas into more concrete experience, so subjects like chemistry, physics, and engineering become easier to understand and more meaningful (Momenipour et al., 2024; Adetunla et al., 2024). In higher education, these tools are useful to build cross-disciplinary skills such as creating mathematical models and learning spatial relations (Alexandrovna et al., 2024; Huang & Tseng, 2025). AR and VR also help in making virtual learning environments (VLEs) for distance education, which can remove geographical barriers and give access to quality education for students living far from campus (Guerra et al., 2024; Al-Azawi et al., 2019). However, there are also challenges in using VR and AR for STEM learning. The high price of devices, the need for strong infrastructure, and the difficulty for teachers to learn the system are big barriers to adoption (Al-Azawi et al., 2019; Momenipour et al., 2024; Prieto Andreu, 2025). There are also health concerns like eye strain or motion sickness when using for long time, and sometimes the content may not match cultural context (Al-Azawi et al., 2019). For better integration, schools and universities must plan carefully and align education, organization, and technology strategies together (Momenipour et al., 2024). Future research should try to develop suitable pedagogy, provide metacognitive support, and test blended models like flipped classroom to increase the benefit of AR and VR (Ibáñez & Delgado-Kloos, 2018; Tene et al., 2024). More long-term studies are also needed to see the real effect on learning results and to solve current problems with technical limitations and usability (Prieto Andreu, 2025; Tene et al., 2024). In conclusion, VR and AR have strong potential to transform STEM education by making learning more interactive and engaging. But their success depends on solving challenges of cost, infrastructure, and teaching methods. With careful research and planning, these technologies can play important role in the future of STEM education.

Mobile and internet apps and websites with gamified interfaces for children interested in STEM.

The use of gamified interfaces in mobile and online applications for children who are learning STEM (Science, Technology, Engineering, and Mathematics) has shown good results for improving engagement, motivation, and learning success. Many studies examine how gamification works in education, especially in informal learning and in specific STEM subjects. For example, one study with a gamified web app for Grade 5 students found that points and leaderboards increased motivation by giving feeling of success and competition, while badges were less effective (Chatzidaki et al., 2025). Another mobile app created to teach fractions for Grade 4 students reported high satisfaction for usability and also positive impact on learning (Solano-Gonzales et al., 2023). A different study showed that combining spaced repetition with gamification in a mobile learning system for K-12 could be very useful for STEM education (Yeh et al., 2016).

Table 3. Gamified Applications in STEM Education: Study Focus, Key Findings, and Implications

Study Focus	Key Findings	Implications
Gamified web application for fifth-grade students (Chatzidaki et al., 2025)	Points and leaderboards increased motivation; badges less effective	Gamification elements can enhance motivation and engagement in informal learning settings
Mobile application for teaching fractions (Solano-Gonzales et al., 2023)	High satisfaction in usability; positive impact on learning outcomes	Gamified mobile apps can improve learning in specific STEM subjects
Spaced repetition and gamification in mobile learning(Yeh et al., 2016)	Potential for fruitful results in STEM education	Combining instructional strategies with gamification can enhance learning outcomes
Gamified mobile app for physical activity (Schafer et al., 2018)	Effective in encouraging physical activity	Gamified feedback can motivate children to engage in healthy behaviors
SmartGame project (Gini et al., 2023)	Supports math learning and fosters interpersonal relationships	Integration of gamified apps with tangible devices can enhance educational experiences
Gamification with modern technologies (Logothetis et al., 2022)	Increased engagement, motivation, and development of soft skills	Combining gamification with advanced technologies can enhance learning experiences
Gamified music note instruction app (Chumpanin et al., 2024)	Enjoyable and intuitive learning experience	Gamification can be effectively applied to non-STEM subjects for educational purposes

Gamified interfaces are also used outside of classroom lessons. One mobile app used to promote physical activity in children applied smartphone sensors to give motivational feedback, and this was effective for encouraging them to be active (Schafer et al., 2018). The SmartGame project joined a gamified web app with an IoT device to help children learn mathematics and improve social relations, especially for those who lost interaction during the pandemic (Gini et al., 2023). A study in Turkey that looked at STEM apps for children found that most apps focused on science and math, but many were missing features such as social interaction or progress tracking (Konca et al., 2024). This shows designers need to make more complete and interactive educational tools.The literature also notes the importance of continuous checking and improvement of gamified tools to fit different types of learners and reduce possible negative impact. One study on gamification in informal science learning stressed that regular evaluation is needed to make these approaches more effective (Chatzidaki et al., 2025). Also, when gamification is combined with new technologies such as virtual worlds and geolocation, it can further increase engagement and motivation, while also building soft skills and positive learning attitude (Logothetis et al., 2022). Gamified interfaces are not limited to STEM only. For example, in music education, a mobile web application with gamification design helped beginners learn music notes in an enjoyable and simple way (Chumpanin et al., 2024). In short, gamified interfaces in mobile and internet applications for children show strong potential to improve engagement, motivation, and learning in STEM. But these tools must be evaluated and improved continuously to make sure they meet the needs of different learners and provide more complete educational experience. The mix of gamification with modern technologies and creative teaching strategies looks very promising for the future of STEM education.

Future Directions and Innovations in Gamification for STEM

The role of AI and adaptive learning in the future of gamification

The use of artificial intelligence (AI) and adaptive learning in gamification for STEM education is expected to change the education system by making learning more personal, engaging, and effective. AI makes gamification stronger by giving real-time feedback, adaptive learning paths, and personalized content for each student. This is possible because AI can study student data and then change the material according to the learner's level, so every student gets the right challenge and support (Kok et al., 2024; Ashley, 2025; Velazquez-Garcia et al., 2025; Mitchell, 2025). For example, the MagicSchool AI platform helps teachers by automating administrative work and creating lesson plans that are customized. In this way, teachers can spend more time on project-based and interactive activities (Ashley, 2025). AI-based gamification can also promote critical thinking, teamwork, and creativity by linking classroom knowledge with real-world problems, so the learning becomes more interesting and meaningful (Ashley, 2025; Bugri & Egala, 2025).The future of gamification with AI and adaptive learning also brings some challenges and ethical issues. Problems like data privacy, bias in algorithms, and the digital divide need careful attention to make sure all students can use these tools fairly (Velazquez-Garcia et al., 2025; Aravind et al., 2025; Bushuyev et al., 2025). Even with these challenges, the benefits are large. AI can manage assessment and provide smart tutoring systems that give feedback and adjust the speed of learning. This is important for keeping students motivated and active (Velazquez-Garcia et al., 2025; Kassenkhan et al., 2025; Srimathi & Anitha, 2025). Also, AI with gamification can help students build important skills like computational thinking, problem solving, and independent decision-making, which are very important in STEM education (Kassenkhan et al., 2025; Tian, 2024). As more schools and universities start to use these technologies, continuous research and changes will be needed to make sure the systems are applied well and give the best results for students (Bushuyev et al., 2025; Bennani et al., 2022).AI and adaptive learning in gamification for STEM education have strong potential to create learning environments that are more personalized, engaging, and effective. By solving the challenges and ethical issues, educators can use these technologies to improve learning outcomes and prepare students better for future success in STEM.

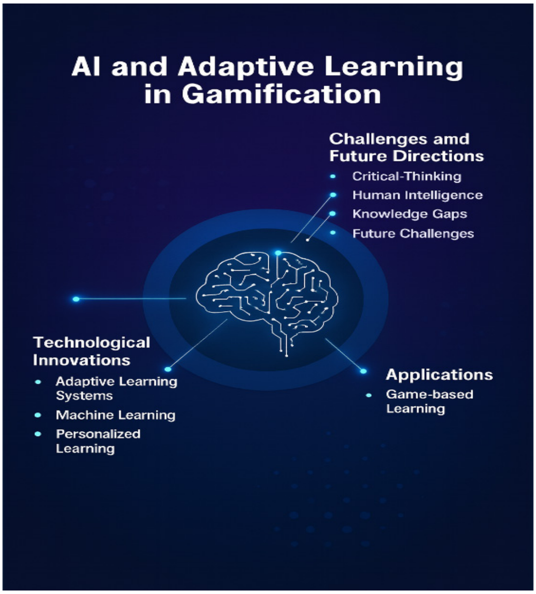

Figure 2. AI and Adaptive Learning in Gamification

Trends That Could Disrupt Labs: Gamification, Blockchain Credentials & Metaverse Learning

The mix of gamification, blockchain credentials, and metaverse learning is becoming an important change in education, with strong potential to transform traditional laboratory practices and improve student learning experience. Gamification, which means using game mechanics in non-game situations, is now seen as a useful method to raise student engagement and motivation. By adding features like points, badges, and leaderboards, gamification can turn normal learning tasks into fun and interactive activities. Many studies show that this approach can improve learning results and make students participate more actively (Tjahjono et al., 2022; Lukita et al., 2024). Blockchain, on the other side, provides secure and transparent way to verify academic records. With decentralized ledgers, blockchain makes credentials tamper-proof and easy to check, increasing trust in educational documents (Tjahjono et al., 2022; Al-Kfairy et al., 2025; Razzaq et al., 2024). The combination of gamification and blockchain can build new education systems that are both motivating and secure, offering a strong framework for modern learning (Tjahjono et al., 2022; Lukita et al., 2024).

The metaverse, which is a virtual world that connects physical and digital spaces, is also seen as a big change for future learning. It uses technologies like virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) to make virtual classrooms, simulations, and gamified learning settings (Al-Kfairy et al., 2025; Peng et al., 2024; Son et al., 2024). These immersive environments can raise student motivation, engagement, and make education more inclusive and easier to access (Al-Kfairy et al., 2025; Peng et al., 2024). Real examples include virtual labs such as SimLab, which give hands-on practice and often produce better results than traditional labs (Son et al., 2024). The metaverse can also support teamwork and reduce the gap between theoretical study and industry practice (Son et al., 2024). But, challenges remain such as high cost of infrastructure, rules and regulations, and ethical concerns, especially about AI decisions (Al-Kfairy et al., 2025; Bushuyev et al., 2025). Future research needs to address these barriers and test the scalability of these approaches to ensure they work effectively (Al-Kfairy et al., 2025; Bushuyev et al., 2025; Hajian et al., 2024). By bringing together gamification, blockchain, and the metaverse has great potential to change education by making it more engaging, secure, and inclusive. However, success will depend on solving problems of infrastructure, regulation, and ethics. More studies are required to overcome these issues and to fully use the transformative power of these new educational technologies.

Table 4. Emerging Trends in Education: Benefits and Challenges of Gamification, Blockchain Credentials, and Metaverse Learning

Trend	Description	Benefits	Challenges	Challenges
Gamification	Application of game mechanics to education	Increased engagement and motivation, improved learning outcomes	Implementation complexity, need for effective design	(Tjahjono et al., 2022) (Lukita et al., 2024)
Blockchain Credentials	Decentralized and secure method for credential verification	Tamper-proof records, enhanced integrity of credentials	Tamper-proof records, enhanced integrity of credentials	(Tjahjono et al., 2022) (Al-Kfairy et al., 2025) (Razzaq et al., 2024)
Metaverse Learning	Virtual environments combining physical and digital realities	Immersive experiences, enhanced engagement, inclusive learning	High infrastructure costs, ethical considerations in AI	(Al-Kfairy et al., 2025) (Peng et al., 2024) (Son et al., 2024)

Policy recommendations for institutional adoption and sustainability

When talking about policy recommendations for adoption and sustainability of gamification in STEM education, it is important to look at both research findings and practical use. Gamification already shows strong potential to improve student motivation, engagement, and learning results in many education contexts, including STEM. But for successful adoption and long-term use, several factors must be considered carefully.

First, the use of gamification in STEM must be based on clear theoretical background and supported by research evidence. Studies prove that gamification can make learning better by increasing engagement, encouraging goal setting, and giving recognition to students (Charkova, 2024; Wang et al., 2024; Yusri & Zainal, 2025). For example, gamification in primary schools has improved performance, motivation, and skills in subjects like language, mathematics, and science (Yusri & Zainal, 2025). At higher education level, gamified strategies have been used in engineering courses to teach sustainability and global issues, with good results (Jain et al., 2022). Still, to make gamification sustainable, it is necessary to conduct long-term studies that measure how it affects engagement and learning over time (Wang et al., 2024; Yusri & Zainal, 2025; Scurati et al., 2020).

Second, the application of gamification should match the specific needs and context of each institution. This means taking into account cultural background, education level, and availability of technology. For instance, a study with adolescents from Europe and Middle East showed that a gamified framework improved hydrogen literacy and sustainability awareness, proving the importance of adaptive and context-sensitive design (Kramar & Knez, 2025). Digital tools like augmented reality and mobile apps can also increase learning by offering interactive and immersive environments (Ma et al., 2023; Despeisse, 2018). But challenges must be addressed, such as digital inequality, lack of teacher training, and ethical concerns about collecting student data (Martín-Rodríguez & Madrigal-Cerezo, 2025).In short, for gamification in STEM education to be adopted and maintained, a full approach is needed. This should include strong theoretical support, real evidence from studies, and context-based practice. By focusing on these aspects, institutions can build effective policies for gamification use in STEM, improving student learning and preparing graduates with skills needed for the 21st century.

Conclusion

Gamification in STEM education shows strong potential to improve student interest, motivation, and achievement. Adding elements like points, badges, leaderboards, and challenge cards into lessons creates more interactive and exciting environments (Teemueangsa & Jedaman, 2021; Mustan, 2025; Al-Hafdi & Alhalafawy, 2024). These approaches are supported by learning theories such as social constructivism and complexity theory, which help in keeping students engaged and in improving knowledge retention (Lottering et al., 2023). Gamification also allows for more personalized learning, where activities and content can match the needs of individual learners, support growth mindset and building new skills step by step (Sawarkar et al., 2024). Even so, challenges remain in bringing gamification into professional education and in meeting the different needs of diverse students (Feng et al., 2024; Rabah et al., 2018). The chapter therefore underlines the importance of continued research and systematic approaches in designing and applying gamified activities (Baldeón et al., 2016; Toda et al., 2019). For teachers, using gamification requires knowledge of both game design and education goals. To be effective, gamification must connect learning outcomes with the right game mechanics, so students not only enjoy but also achieve their goals (Baldeón et al., 2016). Policymakers need to support training and resources that help teachers apply gamification successfully. This means giving access to platforms, tools, and training that can support gamified teaching (Toda et al., 2019; Dicheva et al., 2019). Other stakeholders, such as schools, universities, and technology developers, should work together to create frameworks that match the needs of STEM education. Partnerships and investment in research will help to solve challenges in gamification and make its benefits stronger (Shi et al., 2023; Yadav & Dixit, 2023).

The future of gamification in STEM looks very promising. It can change traditional teaching into more engaging and effective methods. With technology developing fast, gamification will become more advanced, using features such as artificial intelligence and virtual reality to make learning more immersive (Panthalookaran, 2018). When combined with new technologies, gamification can provide adaptive and personalized learning, preparing students for future jobs and skills (Wahab et al., 2024; Ibrahim et al., 2023). More research and development will give knowledge about long-term impacts and best practices, helping teachers to refine their use of gamification (Yusri & Zainal, 2025; Awad et al., 2023). In the end, gamification is a transformative approach for STEM education, offering new solutions to engage students, develop critical skills, and encourage lifelong learning (Tabolina et al., 2021)

Recommendation

Gamification in STEM education has shown strong potential to improve student engagement, motivation, and learning results. Research between 2020 and 2025 points out many aspects of gamification, including how it is applied, how effective it is, and the challenges faced. Gamification means adding game features such as points, leaderboards, badges, and challenges into learning activities to make the process more interactive and motivating (Feng et al., 2024; Chatzidaki et al., 2025; Yadav & Dixit, 2023). Studies confirm that gamification can raise student motivation and participation by giving a sense of success and healthy competition (Chatzidaki et al., 2025; Gaurina & Pavlin, 2025). One study with fifth-grade students using a gamified web app showed that points and leaderboards were very effective in motivating learners, while badges had less impact (Chatzidaki et al., 2025). Gamification also supports better performance and skill building in subjects such as mathematics, science, and engineering (Awad et al., 2023; Yusri & Zainal, 2025; Moreira Parrales et al., 2024).

Still, successful use of gamification in STEM needs careful planning.

Teachers' knowledge and beliefs are very important for success. A study on physics teachers in Croatia found that most of them had a basic understanding and positive view of gamification, but differences appeared by age, teaching experience, and school type. This shows the importance of professional development that fits teachers' backgrounds (Gaurina & Pavlin, 2025). At the same time, gamified activities must match the education goals and student needs. For example, STEM challenge cards let students test different components and devices, which makes the learning more active and hands-on (Mustan, 2025). However, there are also challenges like the need for continuous evaluation, possible negative impacts, and lack of research on long-term results (Chatzidaki et al., 2025; Yusri & Zainal, 2025; Gini et al., 2025).In conclusion, gamification is a promising way to make STEM education more engaging and effective, but its success depends on careful design and ongoing assessment that consider the diverse needs of both students and teachers.

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