

Gamification as a Learner-Centred Pedagogy in Secondary Science Education: Enhancing Engagement, Motivation and Academic Learning

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Abstract

Contemporary secondary education increasingly needs teaching methods that go beyond simply giving information to students and provide opportunities for participation, feedback, teamwork and meaningful learning. Gamification—the planned use of selected game features in non-game educational setting has emerged as a promising learner-centred teaching strategy. This paper explores the educational potential of gamification in secondary Science education, with special focus on student engagement, motivation and academic learning. The paper is conceptually developed around the main themes and ideas presented in a research framework on gamification in secondary education, while intentionally not repeating or depending on its specific sample or statistical findings. Recent systematic reviews generally show positive relationships between gamification and students' motivation, engagement and learning outcomes, although its effects may differ depending on the design, classroom context, learner characteristics and quality of implementation. The paper suggests that gamification becomes most useful when game elements are clearly connected with curriculum objectives, when feedback helps students improve their learning rather than only encouraging competition, and when activities support independence, confidence, cooperation and reflection. A framework is presented connecting game elements with psychological processes and educational outcomes. The paper also highlights challenges such as excessive competition, overdependence on external rewards, unequal access to digital resources, teacher preparedness, alignment with assessment and long-term sustainability. It concludes that gamification should not be seen simply as adding rewards to regular teaching, but as a planned teaching approach that can strengthen student participation and meaningful Science learning when used thoughtfully.

Keywords: gamification, secondary education, Science education, student engagement, motivation, academic learning, learner-centred pedagogy, educational technology

1. Introduction

Education is gradually moving away from mainly teacher-centred teaching, where teachers mostly provide information, towards learning environments that focus on active participation, skill development, digital literacy and students taking greater responsibility for their own learning. This change is especially important in secondary education because students are introduced to more complex and abstract subjects while also going through changes in their attention, motivation, identity and relationships with others. Science education has its own challenges because students are expected not only to remember scientific concepts but also to understand and interpret evidence, apply scientific principles, think logically and scientifically, solve problems and relate what they learn in the classroom to real-life situations.

Traditional teaching methods are still useful for explaining concepts, demonstrating skills and giving students structured practice. However, depending only on lectures, memorisation and exam-focused activities may not give students enough opportunities to actively participate in the learning process. Gamification provides one possible way to make such learning environments more engaging. It involves adding game-like elements—such as points, badges, levels, challenges, progress indicators, feedback and leaderboards—to educational activities. This does not mean that the entire teaching and learning process has to be converted into a game.

The educational value of gamification does not depend only on the game elements used, but more on the behaviours and learning experiences they can create. A well-planned challenge can encourage students to keep trying and not give up easily. Immediate feedback can help students identify their mistakes and correct them quickly. Progress indicators can help students clearly see their learning goals and understand how much they have achieved. Collaborative activities or missions can encourage students to interact, communicate and learn from their classmates. Giving students opportunities to make choices can also help them become more independent and responsible for their learning. However, poorly designed gamification systems can create excessive competition, make students focus only on winning rewards, or create difficulties for students who need more time to learn and progress.

Recent research gives a generally positive but careful view of gamification. A 2023 systematic review of gamified learning strategies in high school and higher education found that points, badges and rankings were commonly used, and gamification was often linked with increased student motivation. A 2024 systematic review also found positive evidence for motivation and academic performance. Another systematic review and meta-analysis published in 2026, which focused on mathematics education in secondary and higher education, found a small-to-moderate positive effect of gamification on student motivation. However, the study also pointed out some limitations in the research methods and noted that there was not enough reliable evidence to measure its effect on student engagement quantitatively. Overall, these findings show that gamification has good potential in education, but its success largely depends on how carefully it is planned, designed and used in the classroom.

2. Conceptualising Gamification in Education

Gamification is different from game-based learning. **Game-based learning** uses an actual game as the main method through which students learn, while **gamification** adds selected game-like elements to an existing teaching activity or learning environment. This difference is important because gamification can easily be included in regular curriculum lessons, laboratory activities, quizzes, projects and revision exercises. Teachers do not need to change or replace the entire teaching structure to use gamification. Instead, they can add suitable game elements to existing classroom activities to make learning more interesting and engaging for students.

Common game elements include points, badges, levels, leaderboards, missions, challenges, avatars, progress bars, rewards and immediate feedback. These elements can be grouped according to the purpose they serve in the learning process. **Progress elements** help students see and understand their learning progress. **Feedback elements** give students information about their performance and help them identify areas for improvement. **Challenge elements** set clear and meaningful goals that encourage students to make an effort and continue learning. **Social elements** promote interaction, teamwork and cooperation among students. **Recognition elements** acknowledge students' achievements and help them feel that their efforts and progress are valued.

However, using game elements does not automatically make learning more effective. A leaderboard may motivate some students, but it may also discourage students who are less confident or who progress at a slower pace. Badges can be useful for recognising students' skills and achievements when they are connected to meaningful learning goals, but they can become less valuable when they are given simply for completing a task. Points can help students see their progress, but relying too much on points may make students focus more on collecting rewards than on actually understanding the concepts. Therefore, the main question is not simply whether game elements are used in the classroom, but whether these elements actually improve students' learning experiences and the quality of their learning activities.

3. Theoretical Foundations

3.1 Self-Determination Theory

Self-Determination Theory provides a useful way to understand how students become motivated in gamified learning environments. The theory explains that students have three important psychological needs: autonomy, competence and relatedness. Gamified activities can support a sense of competence by giving students clear goals, regular feedback and opportunities to see their improvement. They can support autonomy by allowing students to make meaningful

choices during learning activities. Relatedness can be developed through teamwork, group activities and interaction with classmates. However, if gamification depends too much on external rewards such as points, badges or prizes, it may reduce students' natural interest in learning. Students may feel that they are participating only to earn rewards rather than because they genuinely want to learn. Therefore, gamification should encourage students to take responsibility for their learning rather than make them feel controlled by rewards.

3.2 Behavioural and Cognitive Perspectives

From a behavioural point of view, immediate feedback and rewards can encourage students to participate and continue making efforts. However, from a cognitive point of view, gamification is useful only when students are actually thinking deeply about what they are learning. For example, a gamified Science quiz becomes more meaningful when its questions ask students to explain ideas, apply scientific concepts, interpret information or use reasoning skills, rather than simply remember facts and answer quickly. Therefore, gamification should be combined with meaningful thinking and challenging learning tasks. It should support and strengthen students' understanding instead of replacing deeper learning with simple games, quick answers or rewards.

3.3 Constructivist Learning

Constructivist approaches believe that students actively build their understanding through interaction with ideas, problems, classmates and their learning environment. In gamified learning, challenges can provide situations where students explore a problem, try out an idea, receive feedback and improve their understanding based on what they discover. In Science education, this approach can be connected with activities such as inquiry, experiments, problem-solving and teamwork. Students can work together to investigate questions, share their ideas, test possible solutions and develop their understanding through active participation. In this way, gamification can make Science learning more practical, interactive and meaningful rather than limiting students to simply memorising facts and concepts.

4. Gamification and Student Engagement

Student engagement has different dimensions and includes behavioural, emotional and cognitive aspects. Behavioral engagement refers to students' participation in classroom activities, the effort they make and their willingness to continue even when a task is difficult. Emotional engagement relates to students' interest, enjoyment and feeling of being connected to the classroom and their learning. Cognitive engagement refers to the effort students put into understanding concepts, thinking carefully, using learning strategies and developing deeper knowledge. Gamification has the potential to support all three types of engagement. It can encourage students to participate actively, make learning more enjoyable and motivate them to think more deeply about the concepts they are learning.

Behavioral engagement can be improved when students are given clear, short-term goals and can easily see their progress. For example, a Science unit can be divided into a series of small challenges, making a large topic easier to understand and complete step by step. Emotional engagement can be encouraged through new and interesting activities, suitable challenges, recognition of achievement and teamwork. Cognitive engagement depends more on the quality of the learning tasks. Activities such as puzzles, simulations, inquiry-based missions and real-life problem-solving situations can encourage students to think, analyse and reason instead of simply memorising and recalling information.

Recent systematic reviews generally show a positive connection between gamification and student engagement, although the available research is varied in terms of methods and findings. A 2024 review of school engagement identified gamification as a teaching strategy that is being increasingly studied in both primary and secondary education. A 2026 meta-analysis also found positive effects on student motivation, but pointed out that engagement could not be analysed together across studies because many studies did not use reliable and comparable methods to measure engagement. This limitation shows the need for better and more consistent ways of measuring student engagement in future school-based research.

5. Gamification and Student Motivation

Motivation plays an important role in deciding whether students start learning, continue their efforts and manage their own learning activities. In Science education, motivation is particularly important because students often face abstract concepts, difficult scientific terms and problems that require continuous effort and concentration. Gamified learning can provide students with short and regular feedback, helping them clearly see their efforts, progress and achievements.

Intrinsic motivation can be encouraged through curiosity, interesting challenges, enjoyment and a sense of achievement. Extrinsic motivation, on the other hand, may be influenced by recognition, points, badges and competition. An effective gamified learning design should gradually help students move from participating mainly for rewards towards participating because they want to improve their knowledge and skills. For example, a badge should ideally represent a meaningful achievement or skill that a student has developed, rather than simply acting as a decorative reward.

A 2023 systematic review identified points, badges and rankings as commonly used methods for increasing motivation in gamified education. More recent evidence from 2026 found a small-to-moderate positive effect of gamification on motivation in secondary and higher education mathematics. However, the same review also pointed out that competition and comparison with other students may have negative effects on some learners. This highlights the importance of maintaining a balance between competition, cooperation and individual progress when using gamification in education.

6. Gamification and Academic Learning in Science

Academic achievement in Science includes understanding concepts, applying knowledge, using reasoning skills and connecting learning to new situations. Gamification can support these outcomes when learning activities are designed around meaningful thinking and real academic tasks. For example, students can make progress in a mission by explaining why an experiment produced a particular result, interpreting data, solving a problem that involves several steps, or applying a scientific principle to a real-life situation.

Interactive quizzes can give students immediate feedback about their performance, but they should not focus only on simple factual questions. Scenario-based questions can ask students to identify suitable evidence, predict what might happen or explain and justify their conclusions. Digital simulations can also be included in learning missions where students investigate different variables, observe results and make decisions. Collaborative challenges can require groups of students to develop explanations or solve problems together, while giving each student a meaningful role within the team.

Systematic reviews have generally found positive connections between educational gamification and students' academic performance, although the results vary across different studies and settings. Therefore, the most reasonable conclusion is that gamification can support academic learning when its game elements are used to strengthen good teaching practices. Gamification cannot replace proper explanation, regular practice, useful feedback, assessment or the teacher's subject knowledge. Instead, it should be used as a tool that supports these essential parts of effective Science teaching.

7. A Proposed Framework for Gamified Science Learning

Design Component	Immediate Learning Mechanism	Student Experience	Expected Educational Outcome
Challenges and missions	Clear goals and structured difficulty	Purpose and persistence	Sustained participation
Points and progress	Visible evidence of advancement	Sense of competence	Task completion and persistence

Badges/recognition	Feedback on demonstrated accomplishment	Recognition and confidence	Mastery orientation
Interactive quizzes	Immediate formative feedback	Active retrieval and correction	Conceptual reinforcement
Collaborative tasks	Peer interaction and shared problem solving	Relatedness and cooperation	Communication and collaborative learning
Levels/scaffolding	Gradual increase in complexity	Manageable progression	Higher-order learning
Choice and pathways	Learner autonomy	Ownership of learning	Self-regulation and motivation
Reflection/debrief	Connection between activity and concept	Meaning-making	Transfer and deeper understanding

The framework suggests that gamification does not directly improve students' learning outcomes. Instead, game elements first influence students' **motivation, behaviour and learning experiences**, which then affect their learning activities and results. For example, a progress indicator does not directly increase a student's achievement in Science. However, seeing their progress may encourage students to continue working, practise more and make use of feedback. These increased opportunities for practice and improvement can eventually support better learning outcomes. This distinction is important because it shows that gamification works through different psychological and behavioural processes. It is also useful for teachers and researchers when planning, evaluating and improving gamified learning activities.

8. Designing Gamified Science Lessons

Define learning outcomes: Start with the specific learning outcomes of the curriculum. First decide what students should know, understand, apply or create. Only after this should you decide which game elements will be useful.

Turn outcomes into meaningful challenges: Convert learning objectives into interesting missions, challenges or problems. Each challenge should encourage students to use meaningful Science knowledge and thinking skills rather than simply complete a task.

Use feedback effectively: Give students timely and useful feedback. Feedback should clearly explain what they did well, where they made a mistake and what they can do to improve their performance.

Balance competition and cooperation: Use leaderboards carefully because too much competition can discourage some students. Personal progress, team goals and cooperative challenges can create a healthier learning environment and reduce unnecessary comparison between students.

Provide different opportunities for success: Students should have opportunities to learn from their mistakes, try challenging activities again and show their understanding in different ways. This allows students with different learning speeds and abilities to make progress.

Include reflection: After completing a gamified activity, give students time to think about and discuss what they have learned. They should be encouraged to explain what worked, what did not work, why they chose a particular strategy and how they can use the concept in another situation.

Assess learning separately from rewards: Academic assessment should focus on what students have actually learned according to the curriculum. Marks should not be based simply on the number of points, badges or rewards students have collected.

9. Application to Secondary Science

Gamification can be used in different areas of Science according to the needs of each subject. In **Physics**, students can take part in problem-solving missions that require them to apply scientific laws, solve numerical problems and understand diagrams. In **Chemistry**, students can participate in challenges related to laboratory safety, predicting chemical reactions and understanding molecules and their properties. In **Biology**, students can explore topics such as ecosystems, genetics and the human body through case-based missions and problem-solving activities. **Earth and Environmental Science** can use scenario-based challenges related to climate change, natural resources, pollution and sustainability.

These activities become more useful when the game elements are connected to real scientific practices. Students should not simply “win” a Science activity by collecting the most points or completing tasks quickly. Instead, they should succeed by showing **evidence-based thinking, solving scientific problems, planning an investigation or clearly explaining a scientific idea**. In this way, gamification remains a tool for supporting Science learning rather than becoming the main focus of the activity. The game elements should always support students in developing genuine scientific knowledge, skills and understanding.

10. Role of the Teacher

The teacher continues to play a very important role in effective gamified learning. Gamification does not remove the need for teachers to explain concepts, ask questions, identify students’ difficulties, manage the classroom or assess learning. Instead, it changes the way these teaching practices are organised and carried out. Teachers need to choose appropriate game elements, understand how different students may respond to them, monitor students’ participation and adjust the level of difficulty according to their needs.

Teacher training should therefore not focus only on learning how to use particular digital platforms or tools. Teachers should also understand important principles of **motivation, formative assessment, instructional design, digital citizenship, accessibility and the use of learning data**. They should know how to design activities that are suitable for different learners and connected to clear learning goals. Even a technically advanced or attractive gamified activity may not be educationally effective if it does not have clear learning outcomes or does not provide students with meaningful opportunities to think, apply knowledge and develop deeper understanding.

11. Challenges and Ethical Considerations

Excessive competition: Leaderboards and ranking systems may motivate some students, but they can also make other students feel discouraged or less confident. Using personal progress, team goals and cooperative activities can create a more inclusive learning environment.

Dependence on external rewards: When rewards become the main reason students participate, their natural interest in learning and focus on mastery may decrease. Rewards should be used to recognise meaningful learning and achievement rather than replace students’ interest in learning.

Digital inequality: Technology-based gamification can increase differences between students when they do not have equal access to devices, reliable internet connections or the digital skills needed to participate effectively.

Teacher workload: Creating missions, preparing feedback systems and developing digital resources can require considerable time and effort. Reusable activity templates, shared resources and collaborative planning among teachers can help reduce this workload.

Assessment validity: The points or badges students collect during gamified activities should not automatically be considered proof of academic achievement. Formal assessments should continue to measure the specific learning outcomes and knowledge students are expected to develop.

Privacy and data: Digital platforms may collect and store information about students. Schools and teachers should select and use such platforms responsibly while following appropriate privacy, safety and child-protection requirements.

Accessibility: Gamified activities should provide different ways for students to participate. This is important so that students with different abilities, learning needs or limited access to technology are not left behind or placed at a disadvantage.

12. Implications for Schools and Curriculum Developers

Schools that want to introduce gamification should see it as a **teaching and learning approach**, rather than simply buying new technology or digital tools. A successful and long-lasting approach requires support from school leaders, proper teacher training, suitable infrastructure, teamwork among teachers and regular evaluation of students' learning outcomes. Curriculum developers can also support teachers by providing collections of challenges, formative quizzes, inquiry-based missions and flexible templates that can be adapted according to the needs of different classes and local situations.

At the policy level, gamification can support wider educational goals such as **experiential learning, skill development, digital literacy and learner-centred education**. However, educational policies should focus on encouraging well-planned and evidence-based use of gamification rather than requiring schools to use particular digital platforms, games or reward systems. The main focus should remain on improving students' learning, participation and overall educational experience.

13. Directions for Future Research

1. Conduct **long-term studies** to find out whether the positive effects of gamification on students' motivation and engagement continue after the initial excitement and novelty of gamified activities decreases.
2. Use **reliable and validated methods** to measure different types of student engagement, including behavioural, emotional and cognitive engagement.
3. Report **effect sizes and confidence intervals** along with statistical significance so that researchers can better understand the actual strength and reliability of the results.
4. Examine how students with different levels of **previous achievement, self-confidence, digital skills and individual characteristics** respond to gamified learning.
5. Compare different approaches to gamification, including **competitive, cooperative and mastery-focused designs**, to identify which approaches are most effective for different learners.
6. Study the use of gamification in **Indian secondary Science classrooms** across different educational boards, regions and types of schools to understand how it works in different contexts.
7. Explore how gamification can be combined with emerging technologies such as **Artificial Intelligence, adaptive learning, augmented reality and virtual laboratories** to improve Science learning.
8. Study **teacher readiness, workload, professional training and the quality of implementation** to understand the practical requirements for successful gamification.
9. Evaluate the **cost, accessibility, digital equality and long-term sustainability** of gamification to determine whether schools can use these approaches effectively and maintain them over time.

14. Conclusion

Gamification is a promising approach for making secondary Science learning more focused on student participation, feedback, challenges, teamwork and learner independence. The research discussed in this paper generally shows a positive connection between gamification, student motivation, engagement and academic learning. However, these positive results do not happen automatically and may not be the same for every student or classroom. The effectiveness of gamification depends on the quality of the teaching design, the game elements selected, the needs and characteristics of students and the way gamification is implemented in the classroom.

In secondary Science education, gamification is likely to be most effective when it focuses on learning and mastery rather than rewards. Students should make progress because they are solving meaningful scientific problems, interpreting evidence, explaining scientific phenomena and developing a deeper understanding of concepts, rather than simply collecting points or badges. When gamification is combined with inquiry-based learning, formative assessment, teamwork and reflection, it can become a useful teaching approach for making Science education more learner-centred, meaningful and engaging.

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