

Enhancing the Creativity of Students with Disabilities through STEM-Based Science Learning Games

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Abstract

Inclusive education in primary schools requires accessible, adaptable science learning materials that support students with disabilities' creative thinking. However, the integration of STEM, gamification, and accessibility principles in science learning games for inclusive classrooms remains limited. This study offers a novel approach by developing an accessible STEM-based science learning game to enhance the creativity of students with disabilities in inclusive primary schools. The study aimed to design, develop, and evaluate an accessible STEM-based science learning game integrated with gamification elements. Using a Design-Based Research (DBR) approach, the study involved three phases: needs analysis, prototype development and expert validation, and classroom implementation with refinement. Participants were 24 fourth-grade students, including 6 with disabilities, from an inclusive primary school in Bogor, Indonesia. Data were collected through expert validation sheets, creativity pre- and posttests, questionnaires, observations, and teacher reflections. The developed game, *Eco-Rescue STEM Adventure*, included STEM problem-solving tasks, gamification features, audio instructions, adaptive difficulty levels, and simplified navigation. Expert validation showed high feasibility ($M = 3.71/4.00$). Results indicated significant improvement in creative thinking, with a high average gain score (1.41), while student responses highlighted strong engagement and support for creative learning in inclusive science education.

Keywords: Creative Thinking, Design-Based Research, Gamification, Inclusive Primary Education, STEM Education.

Abstrak

Pendidikan inklusif di sekolah dasar memerlukan media pembelajaran IPA yang aksesibel dan adaptif untuk mendukung keterampilan berpikir kreatif siswa berkebutuhan khusus. Namun, integrasi pendekatan STEM, gamifikasi, dan prinsip aksesibilitas dalam *game* pembelajaran IPA untuk kelas inklusif masih terbatas. Penelitian ini menawarkan kebaruan melalui pengembangan *game* pembelajaran IPA berbasis STEM yang aksesibel untuk meningkatkan kreativitas siswa berkebutuhan khusus di sekolah dasar inklusif. Penelitian ini bertujuan untuk merancang, mengembangkan, dan mengevaluasi *game* pembelajaran IPA berbasis STEM yang terintegrasi dengan elemen gamifikasi. Penelitian menggunakan pendekatan *Design-Based Research* (DBR) yang terdiri atas tiga tahap: analisis kebutuhan, pengembangan prototipe dan validasi ahli, serta implementasi dan penyempurnaan di kelas. Partisipan penelitian adalah 24 siswa kelas IV, termasuk enam siswa berkebutuhan khusus, di sebuah sekolah dasar inklusif di Bogor, Indonesia. Data

dikumpulkan melalui lembar validasi ahli, tes kreativitas pre-test dan post-test, angket, observasi, dan refleksi guru. *Game* yang dikembangkan, *Eco-Rescue STEM Adventure*, memuat tugas pemecahan masalah berbasis STEM, fitur gamifikasi, instruksi audio, tingkat kesulitan adaptif, dan navigasi sederhana. Hasil validasi ahli menunjukkan tingkat kelayakan yang tinggi ($M = 3,71/4,00$). Hasil implementasi menunjukkan peningkatan signifikan pada kemampuan berpikir kreatif dengan rata-rata gain skor tinggi (1,41), sementara respons siswa menunjukkan keterlibatan dan dukungan yang kuat terhadap pembelajaran kreatif dalam pendidikan IPA inklusif.

Kata Kunci: Berpikir Kreatif, *Design-Based Research*, Gamifikasi, Pendidikan Dasar Inklusif, Pendidikan STEM.

INTRODUCTION

Inclusive education has emerged as a global priority that emphasizes equitable access, participation, and learning outcomes for all students, including those with disabilities. In the context of inclusive primary schools, the challenge extends beyond providing physical access to ensuring meaningful, adaptive, and engaging learning experiences that foster 21st-century skills (Altakhaineh et al., 2026; Ramsey et al., 2026; Vira et al., 2026). One of the most critical competencies to be developed is creativity, which enables students to solve problems, think flexibly, and generate innovative ideas. The urgency of strengthening creativity is reflected in the PISA 2022 Results on Creative Thinking, which show that only 5% of Indonesian students reached the top proficiency levels, compared with the OECD average of 27% (OECD, 2024).

At the same time, inclusive education still faces substantial challenges, as children with disabilities continue to experience unequal access to education and learning support (Bani Odeh & Lach, 2024; Gongotha & Bala, 2025; Indonesia, 2023). These conditions indicate that inclusive science learning should not only provide access, but also support the development of higher-order thinking skills, including creativity, among students with disabilities. These challenges are often associated with limited instructional strategies, inadequate learning media, and the lack of adaptive pedagogical approaches. Science education inherently has substantial potential to promote creativity through inquiry, experimentation, and problem-solving.

The Science, Technology, Engineering, and Mathematics (STEM) approach has been widely recognized as an effective framework for enhancing higher-order thinking skills, including creativity (Ayanwale & Omeh, 2026; Rücker & Becker-Genschow, 2025; Sangsawang, 2026; Setiasih et al., 2026; Wiratman et al., 2023). By integrating multiple disciplines, STEM facilitates complex cognitive processes, such as designing solutions, testing hypotheses, and reflecting on outcomes. Nevertheless, STEM implementation in

inclusive primary education remains constrained, particularly in adapting instruction to the diverse needs of students with disabilities (Samaniego López et al., 2025; Wieselmann et al., 2025).

Many STEM-based instructional designs have yet to incorporate accessibility principles, thereby limiting their capacity to provide equitable learning opportunities for all learners. In parallel, rapid advances in digital technology have created new opportunities to develop interactive, engaging learning media. Gamification, as the integration of game elements into non-game contexts, has been shown to enhance student motivation, engagement, and overall learning experiences (Blanco et al., 2023; Legaki et al., 2020; Vanaclocha-Amat et al., 2026). Elements such as points, levels, challenges, and immediate feedback can encourage active participation in learning processes.

Despite its potential, the integration of gamification within STEM education, especially in inclusive settings, remains limited (Regaço et al., 2026; Schultze et al., 2026). Existing gamified learning environments often fail to adequately address accessibility considerations, including intuitive navigation, multimodal representation (visual, auditory, and kinesthetic), and differentiated levels of difficulty (Gini et al., 2025; Kassenkhan et al., 2025; Lavoué et al., 2019; Smith & Abrams, 2019). The gap between the potential of STEM and gamification approaches and their actual implementation in inclusive classrooms underscores the urgent need for more adaptive, inclusive instructional innovations.

This condition arises because students in inclusive classrooms often require more specialized educational support and tailored instructional strategies than students in regular classroom environments (Korthals Altes et al., 2024; MacKenzie et al., 2023; Soeharto et al., 2024). Therefore, this study aims to develop an accessible STEM-based science learning game that integrates gamification elements to support students with disabilities in inclusive primary schools. This development effort is not only intended to produce a functional educational tool but also to propose an instructional design model that can guide teachers in implementing innovative and inclusive learning practices.

RESEARCH METHODS

This study employed a Design-Based Research (DBR) approach to systematically design, develop, and evaluate an accessible STEM-based science learning game to enhance students with disabilities' creative thinking skills in inclusive primary school settings. DBR was selected because of its iterative, flexible, and intervention-oriented nature, enabling

continuous refinement of both the educational product and its underlying design principles through repeated cycles of implementation, reflection, and revision (Hoadley & Campos, 2022; Tinoca et al., 2022).

The study was conducted at an inclusive primary school in Bogor, Indonesia, involving 24 fourth-grade students: 18 regular students and 6 students with diverse learning needs, including mild hearing impairment, slow learning characteristics, and attention difficulties. Participants were selected using purposive sampling to ensure adequate representation of inclusive classroom characteristics. In addition, two classroom teachers and three experts in science education, educational technology, and inclusive education participated as key stakeholders during validation and reflection stages. The research procedure consisted of three iterative DBR cycles, each involving analysis, design, implementation, evaluation, and revision.

In the first cycle (needs analysis and initial design), classroom observations, semi-structured interviews with teachers, and document analysis were conducted to identify challenges related to science instruction, creativity development, and accessibility barriers faced by students with disabilities. The findings indicated limited use of interactive media, insufficient differentiation strategies, and low student engagement during science learning activities. Based on these findings, initial design requirements were established. The second cycle (prototype development and expert validation) focused on developing the prototype of the game by integrating STEM learning principles, gamification elements (points, badges, levels, challenges, and immediate feedback), and accessibility features such as audio instructions, multimodal content presentation, simplified navigation, and adaptive difficulty levels (Das et al., 2025; Suárez-López et al., 2023).

The prototype was then evaluated by three experts using a structured validation instrument covering four aspects: content relevance, instructional design, usability, and accessibility. Expert feedback was used to revise the interface layout, adjust challenge complexity, and improve accessibility support. The third cycle (classroom implementation and refinement) involved a pilot implementation across six instructional sessions conducted over three weeks. Students engaged with *Eco-Rescue STEM Adventure* during science learning activities focusing on environmental conservation and energy transformation concepts.

Observational field notes were collected to document student engagement, interaction patterns, accessibility issues, and learning responses. Reflection meetings with teachers were conducted after each implementation session to identify areas for further

improvement. To evaluate effectiveness, a pretest and posttest design was employed to measure students' creative thinking skills across four dimensions: fluency, flexibility, originality, and elaboration, adapted from Torrance's creative thinking indicators. The creativity assessment instrument consisted of eight open-ended problem-solving tasks contextualized within science learning scenarios. Instrument validity was established through expert judgment, while reliability testing yielded a Cronbach's alpha coefficient of 0.87, indicating high internal consistency.

Additional data were collected through student response questionnaires and teacher reflection sheets. The student questionnaire consisted of 15 Likert-scale items assessing usability, engagement, attractiveness, and perceived learning effectiveness. Teacher reflections provided qualitative insights regarding implementation feasibility and inclusivity. Data analysis employed both quantitative and qualitative approaches. Descriptive statistics were used to summarize expert validation scores, observation results, and questionnaire responses. Inferential analysis using paired sample t-tests was conducted to examine differences between pretest and posttest creativity scores at a significance level of $p < .05$. Effect size was calculated using Cohen's d to determine the magnitude of improvement.

Qualitative data from observations and reflection notes were analyzed thematically to identify recurring patterns related to engagement, accessibility, and creative learning processes. Through these iterative cycles, the study generated three primary design principles for inclusive STEM game development: (1) accessibility must be embedded as a core design element rather than an additional feature; (2) gamification should support meaningful problem-solving rather than merely reward completion; and (3) adaptive challenge structures are essential for accommodating diverse learner profiles in inclusive classrooms.

RESULTS AND DISCUSSION

Results

The developed game, entitled *Eco-Rescue STEM Adventure*, integrates STEM content, gamification elements, and accessibility features into a unified learning environment. Expert validation results indicate that the media is highly valid and appropriate for instructional use. Furthermore, the field implementation findings demonstrate a significant improvement in students' creative thinking skills. The development process resulted in an accessible STEM-based science learning game that

incorporates gamification principles. The game integrates key gamification elements, such as points, badges, and levels, alongside accessibility features including audio instructions, simplified navigation, and adaptive difficulty levels to accommodate diverse learner needs. *Eco-Rescue STEM Adventure* is structured into four main levels: environmental problem-solving, engineering design challenges, energy conservation tasks, and open-ended creative challenges. These levels are designed to engage students in meaningful learning experiences while fostering creativity through interactive, inclusive gameplay.



Figure 1. User Interface Components of *Eco-Rescue STEM Adventure*

The visual interface examples presented in Figure 1 illustrate the main components of *Eco-Rescue STEM Adventure*. The figure includes the main navigation display, STEM-based problem-solving activities, and accessibility configuration features. These examples show how the game provides intuitive access to learning modules, supports interactive science tasks, and offers accessibility options, including audio support, simplified navigation, visual customization, and adaptive difficulty settings for students with diverse learning needs.

Expert Validation Results

The developed game was evaluated by three experts in science education, educational technology, and inclusive education. The expert validation results indicate that the game achieved a high level of validity: content validity was rated as very valid ($M = 3.75/4.00$), media usability was categorized as very good ($M = 3.68/4.00$), and accessibility

was assessed as highly appropriate. These findings demonstrate that the developed game has high validity and is suitable for implementation in inclusive classroom settings.

Table 1. Expert Validation Results of the Developed Product

Assessment Aspect	Indicators	Mean Score	Category
Content Feasibility	Alignment with STEM content	3.80	Very Valid
	Concept integration	3.70	Very Valid
Media Feasibility	Interface design	3.65	Very Good
	Ease of use	3.70	Very Good
Gamification	Points, levels, badges	3.60	Good
	Game attractiveness	3.75	Very Good
Accessibility	Audio instructions	3.80	Very Good
	Simple navigation	3.70	Very Good
	Adaptive difficulty	3.65	Very Good
Overall Mean		3.71	Very Valid

Effectiveness of Trial Results

Before the product's widespread use, the effectiveness of the developed game was examined using a pretest-posttest design, with a primary focus on students' creative thinking skills. This approach aimed to determine the extent to which implementing *Eco-Rescue STEM Adventure* contributed to improvements in creativity after the intervention. The results of this trial are crucial because they determine whether the resulting product contributes to the quality of the learning process and outcomes. The trial results are shown in Table 2.

Table 2. The Effectiveness

Aspect	Pretest	Posttest	Gain
Fluency	2.12	3.56	1.44
Flexibility	1.98	3.37	1.39
Originality	1.76	3.18	1.42
Elaboration	2.24	3.61	1.37

The trial results presented in Table 2 demonstrate a substantial improvement in students' creative thinking skills following the implementation of *Eco-Rescue STEM Adventure*. All measured dimensions showed positive gains, indicating that the developed STEM-based learning game effectively supported creativity enhancement among students in inclusive classroom settings. The highest gain score was observed in fluency (1.44), suggesting that students became more capable of generating multiple relevant ideas during science problem-solving activities. Originality also showed a notable increase (1.42), reflecting students' improved ability to produce unique and innovative responses.

Meanwhile, flexibility (1.39) and elaboration (1.37) demonstrated consistent improvement, indicating that students developed stronger abilities to approach problems

from multiple perspectives and elaborate their ideas in greater detail. Although slight variations were identified among the gain scores, all creativity dimensions fell within the great improvement category. A paired-samples t-test further confirmed that the improvement was statistically significant ($p < .05$), indicating that the intervention had a meaningful positive effect on students' creative performance.

Improvement in Students' Creative Thinking Skills

Referring to the effectiveness of previous trial results, one of the indicators focused on in this study is creative thinking skills, which consist of four aspects: fluency, flexibility, originality, and elaboration. These four aspects are essential components for identifying the extent to which the learning process and outcomes have contributed to the development of these abilities. Table 3 presents the results of improvements in students' creative thinking skills based on a comparison of pretest and posttest scores obtained after the learning implementation.

Table 3. Students' Creative Thinking Skills				
Creativity Aspect	Pretest (Mean)	Posttest (Mean)	Gain	Improvement Category
Fluency	2.12	3.56	1.44	High
Flexibility	1.98	3.37	1.39	High
Originality	1.76	3.18	1.42	High
Elaboration	2.24	3.61	1.37	High
Average	2.03	3.43	1.41	High

Table 3 demonstrates a substantial improvement in students' creative thinking skills across all measured aspects following the intervention. The mean scores increased notably from pretest to posttest, indicating that the implementation of *Eco-Rescue STEM Adventure* positively contributed to students' creativity development. The highest gain was observed in fluency (1.44), suggesting that students became more capable of generating multiple relevant ideas during problem-solving activities.

Originality also increased significantly (1.42), reflecting students' improved ability to produce novel responses. Meanwhile, flexibility (1.39) and elaboration (1.37) improved consistently, indicating enhanced capacity to approach problems from diverse perspectives and to develop ideas in greater detail. Although slight variations were found among the gain scores, all aspects fall within the great improvement category. This pattern suggests that the game effectively supported the balanced development of multiple dimensions of creative thinking among students with disabilities in an inclusive learning environment.

Students' Responses to the Learning Game

The analysis results in the two previous tables indicate that implementing the learning game significantly improved students' creative thinking skills. This finding aligns with the effectiveness trial's results, which indicated a positive impact of *Eco-Rescue STEM Adventure* on students' creative performance. Although the quantitative data have demonstrated the intervention's success in terms of learning outcomes, evaluating students' acceptance and experience is also necessary to obtain a more comprehensive picture of the game's quality.

Student responses are an important indicator because user acceptance can influence engagement, motivation, and the sustainability of media use in learning activities. Therefore, this study also examined students' perceptions of the learning game across several key aspects, including enjoyment, ease of use, contribution to the development of creative thinking, appeal to science learning, and ability to help students understand the material being studied. The results of student responses to these five aspects are presented in Table 4.

Table 4. Students Response

Statement	Percentage (%)	Category
The game is enjoyable	85%	Very Good
The game is easy to use	82%	Very Good
The game helps develop creative thinking	88%	Very Good
The game is engaging for science learning	86%	Very Good
The game helps in understanding the material	84%	Very Good

The results of students' responses to the learning game indicate a highly positive perception across all assessed aspects. The statement "The game helps develop creative thinking" had the highest percentage at 88%, categorized as Very Good, indicating that students perceived the game as effective in stimulating their creative thinking. That was followed by "The game is engaging for science learning" (86%) and "The game is enjoyable" (85%), both rated Very Good, suggesting that the game successfully created an engaging and enjoyable learning environment.

Furthermore, "The game helps in understanding the material" received 84%, demonstrating that the game effectively supported students' comprehension of science concepts. The lowest percentage was 82% for "The game is easy to use," which still falls within the Very Good category. Overall, these findings indicate that the learning game was well-received by students and has strong potential as an innovative instructional medium for enhancing creativity and science learning outcomes.

Discussion

The results of this study show that *Eco-Rescue STEM Adventure* is a valid and feasible learning medium for inclusive science instruction. The expert validation results indicate that the integration of STEM content, gamification elements, and accessibility features was considered appropriate for classroom implementation. This finding is consistent with previous research that inclusive STEM learning media should not only deliver science content but also provide adaptive and accessible learning experiences for students with diverse needs (Arnab et al., 2025; Bienkowska, 2015).

The accessibility features embedded in the game, such as audio instructions, simplified navigation, and adaptive difficulty levels, are important for supporting students with disabilities in inclusive classrooms (Samaniego López et al., 2025). These features help reduce learning barriers and make the learning process more accessible. It is relevant to the challenges commonly found in inclusive education, where students require learning media and instructional strategies that are responsive to their individual needs.

The improvement in students' creative thinking skills suggests that the STEM-based problem-solving activities in the game fostered creativity. Through environmental problem-solving, engineering design challenges, energy conservation tasks, and open-ended creative challenges, students were encouraged to generate ideas, explore alternative solutions, and elaborate their thinking. These findings suggest that integrating STEM principles, gamification elements, and accessibility features created an engaging and adaptive learning environment that effectively stimulated students' creative thinking.

The increase across fluency, flexibility, originality, and elaboration also indicates that the game supported different dimensions of creative thinking. The improvement in fluency shows that students produced more relevant ideas, while the increase in originality indicates that they were encouraged to develop more unique responses. Improvements in flexibility and elaboration suggest that students became more capable of approaching problems from various perspectives and developing their ideas in more detail. These results show that accessible, game-based STEM learning can provide a meaningful context for developing students' creativity, even those with disabilities.

The positive student responses further indicate that gamification elements contributed to students' engagement in science learning. Points, badges, levels, challenges, and immediate feedback helped make the learning process more enjoyable and interactive. These findings align with several studies in different contexts, which showed that implementing gamification increased elementary school teachers' satisfaction, intention,

and engagement in a training program. These different contexts indicate that gamification positively impacts the learning process and outcomes for both elementary school students and teachers (Liu et al., 2023; Wieselmann et al., 2025). Therefore, the use of gamification in this study did not merely function as a reward mechanism but also supported students' active participation and creative learning experiences.

Conceptually, this study advances inclusive science education by offering a practical instructional innovation that addresses students' specific learning needs in inclusive classrooms. The results also highlight the importance of designing technology-supported learning media that not only promote academic understanding but also foster higher-order thinking skills, particularly creativity. Therefore, this study provides both empirical evidence and design implications for developing more inclusive and innovative science learning practices in primary education.

CONCLUSION

This study concludes that *Eco-Rescue STEM Adventure* is a valid, feasible, and effective learning medium for enhancing the creative thinking skills of students with disabilities in inclusive primary science classrooms. The findings show that accessible, gamified STEM learning can support improvements in fluency, flexibility, originality, and elaboration, while also encouraging positive student engagement. Beyond its empirical findings, this study emphasizes the need to design inclusive science learning media that are not only interactive and motivating but also responsive to diverse learner needs. Therefore, the developed game may serve as a practical reference for teachers and instructional designers in creating accessible, creativity-oriented science learning experiences in primary education.

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