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Research and Development of "Si Pegi" Gamification Learning Media for the Effectiveness of Fourth Grade Elementary School Science Learning Outcomes

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ABSTRACT

Learning Natural and Social Sciences (IPAS), an integration of science and social curriculum regarding energy change material in elementary schools, is often considered difficult due to its abstract nature and the minimal use of interactive media. This has an impact on low student learning outcomes. This study aims to develop a gamification-based learning media named "Si Pegi" as an abbreviation of "Gamification of Energy Change" which is valid, practical, and effective in order to improve science learning outcomes (IPAS) of fourth-grade elementary school students. The research method used is Research and Development (R&D) with a 4D development model that includes the Define, Design, Develop, and Disseminate stages. The research subjects consisted of 18 fourth-grade students of SDN 11 Sitiung as the main trial subjects and 18 students of SDN 10 Sitiung as the dissemination stage subjects. Data collection instruments included expert validation sheets, teacher and student response questionnaires, and learning outcome tests. The results showed that the "Si Pegi" media was declared very valid with an average score of 94.66% from the experts. The practicality level reached 89.95%, categorized as very practical, based on user feedback. Effectiveness testing demonstrated a significant improvement in learning outcomes, with 88.88% of students achieving the completion criteria. Thus, the "Si Pegi" media has proven to be an innovative tool capable of transforming abstract science concepts into concrete and enjoyable learning experiences, optimizing science learning outcomes in elementary schools.

Keywords: gamification; learning media; learning outcomes; research and development; science

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ABSTRAK

Pembelajaran Ilmu Pengetahuan Alam dan Sosial (IPAS) sebuah integrasi kurikulum sains dan sosial mengenai materi perubahan energi di sekolah dasar sering kali dianggap sulit karena sifatnya yang abstrak dan minimnya penggunaan media interaktif. Hal ini

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berdampak pada rendahnya hasil belajar siswa. Penelitian ini bertujuan untuk mengembangkan media pembelajaran berbasis gamifikasi yang diberi nama "Si Pegi" sebagai singkatan dari “Gamifikasi Perubahan Energi” yang valid, praktis, dan efektif guna meningkatkan hasil belajar sains (IPAS) murid kelas IV Sekolah Dasar. Metode penelitian yang digunakan adalah *Research and Development* (R&D) dengan model pengembangan 4D yang meliputi tahap *Define, Design, Develop, dan Disseminate*. Subjek penelitian terdiri dari 18 siswa kelas IV SDN 11 Sitiung sebagai subjek uji coba utama dan 18 siswa SDN 10 Sitiung sebagai subjek tahap penyebaran. Instrumen pengumpulan data mencakup lembar validasi ahli, angket respons guru dan siswa, serta tes hasil belajar. Hasil penelitian menunjukkan bahwa media "Si Pegi" dinyatakan sangat valid dengan skor rata-rata 94,66% dari para ahli. Tingkat praktikalitas mencapai 89,95% dalam kategori sangat praktis berdasarkan respon pengguna. Uji efektivitas menunjukkan peningkatan signifikan pada hasil belajar dengan 88,88% siswa mencapai kriteria ketuntasan. Dengan demikian, media "Si Pegi" terbukti menjadi sarana inovatif yang mampu mentransformasi konsep sains yang abstrak menjadi pengalaman belajar yang konkret dan menyenangkan guna mengoptimalkan hasil belajar sains di sekolah dasar.

Kata Kunci: Gamifikasi, Si Pegi, IPAS, Hasil Belajar, Media Pembelajaran.

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INTRODUCTION

Education is the primary foundation for shaping the character and intelligence of the nation. As mandated by Law of the Republic of Indonesia Number 20 of 2003 concerning the National Education System (SISKNAS), education is a conscious and planned effort to create an environment and learning process that enables students to actively develop their potential to possess spiritual and religious strength, self-control, personality, intelligence, noble character, and the skills needed for themselves, society, the nation, and the state. Globally, the discourse on educational transformation emphasizes that scientific literacy is not merely mastery of material, but rather the ability to adapt to changing times through an integrative pedagogical framework.

Today's education demands problem-solving processes that are relevant to current developments, including the use of technology in learning (Ratinho & Martins, 2023). Information technology has advanced rapidly and transformed the way society obtains information, not only through conventional media but also through electronic sources and the internet. The use of information technology in learning has now become a necessity and a demand to improve the quality of education. One form of technology application in education is through the development of learning media. This technology integration aligns with Candido & Cattaneo (2025) Cognitive Theory of Multimedia Learning (CTML), which states that individuals learn better from words and images than from words alone. Therefore, cognitive efficiency can be achieved through balanced visual and auditory stimulation.

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Learning media is anything that can convey messages through various channels. Learning media can help stimulate students' thoughts, feelings, and interests, thereby encouraging the learning process, adding new information and knowledge to students, and enabling them to effectively achieve learning objectives (An, 2021). The use of appropriate media can facilitate students' understanding of material with abstract or complex concepts, or that requires visualization of processes by making them more concrete and tangible. Engaging learning media can also increase students' interest and motivation to learn, encourage exploration, and connect the subject matter to everyday life (Amini et al., 2026). Therefore, selecting the right media is crucial, especially in subjects that involve extensive observation of phenomena in real-world contexts. One such subject is Natural and Social Sciences (IPAS).

Natural Sciences (IPAS) is a fundamental subject designed to integrate students' understanding of the natural environment (science) and social interactions (social studies) around them (Anggita et al., 2023). Through IPAS education, students are expected to not only memorize facts but also develop critical, logical, and analytical thinking skills in solving problems related to everyday life, as well as fostering awareness of environmental and social issues. The essence of IPAS at the elementary school level is not simply the transfer of knowledge, but the development of scientific investigations in which students act as subjects, empirically exploring natural phenomena.

One fundamental topic in IPAS is the transformation of energy forms in the surrounding environment. Energy is a concept underlying the development of science and technology, encompassing an understanding of various forms of energy and how they can transform from one form to another. However, this topic is often considered difficult and confusing by students. One reason is the abstract nature of matter; students cannot directly see or touch "energy" itself, but can only observe its effects or changes. Understanding the law of conservation of energy also requires abstract thinking skills that elementary school students have not yet fully developed.

Conventional science lessons on energy transformations in the environment often rely on static learning media such as two-dimensional images or diagrams in textbooks, along with verbal explanations with minimal demonstrations. These media have fundamental limitations because energy is an abstract concept, failing to provide interactive and contextual experiences for students to deeply visualize the flow of energy transformations. This phenomenon creates a "cognitive overload" where students struggle to build their understanding due to the limitations of dynamic visualizations in static media (Freitas et al., 2025).

Observations at SDN 11 Sitiung found that the learning process is still dominated by lectures without the support of innovative media or visual aids. This reliance on lectures creates a significant gap because students' learning styles are highly diverse, encompassing visual, auditory, and kinesthetic styles, which cannot be optimally accommodated through verbal explanations alone. As a result, students tend to quickly become bored, pay less attention, and lose interest during the teaching and learning process. The inability of conventional media to dynamically visualize energy transformations results in students lacking a deep understanding of the material, which ultimately negatively impacts learning outcomes. Assessment data shows that 67% of students have not yet achieved the Learning Objective Achievement Criteria (KKTP). Therefore, intermediaries or media are needed that can transform abstract ideas into concrete concepts for the recipient (Garden & Palmer, 2021). The gap between students' learning style needs and the availability of media in schools requires technological interventions capable of fostering intrinsic motivation, so that active student engagement in the learning process can impact improved science learning outcomes (IPAS).

Based on the problems described above and along with technological developments, gamified learning media has emerged as an innovative solution to address the challenges of abstract learning and the lack of student interactivity. In education, gamification is the process of integrating learning activities and transforming content into game-like experiences using game elements (Khaldi et al., 2023). The use of gamification in this learning also aligns with the characteristics of elementary school students belonging to Generation Alpha. This age group was born and raised in a highly digital environment and is accustomed to instant interactions, rich visuals, and rapid feedback mechanisms similar to those found in games. The use of gamified media also encourages two-way communication between the media and its users, creating a more personalized and immersive learning experience

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(Gini et al., 2025). Theoretically, gamification is supported by Self-Determination Theory (SDT), which emphasizes the importance of autonomy, competence, and relatedness in enhancing students' intrinsic motivation to complete complex cognitive tasks (Gilroy et al., 2026).

The application of gamified learning media offers a more interactive and enjoyable learning experience. This media can include elements such as points, badges, leaderboards, challenges, animations, simulations, interactive quizzes, and educational games relevant to the topic of energy transformation in the environment (Hong et al., 2024). These features enable students to visualize abstract energy transformation processes, such as the conversion of kinetic energy to sound, through dynamic illustrations and simulations, thus facilitating and concrete conceptual understanding (Elsawah, 2025). Various software tools are available to assist in developing gamified media, one of which is the Canva application.

Canva is a highly popular and functional application for creating e-learning content and interactive learning media. Canva is a graphic design application that serves as a bridge for its users in terms of design, making it easy for them to create various types of creative materials online (Jamaludin & Sedek, 2023). Canva is equipped with pages and design elements combined with features such as text, images, video, audio, and interactive elements (like buttons and animations), making the resulting learning media more interactive. Thus, Canva not only provides an interactive learning experience through dynamic visual elements but also allows students to explore the subject matter in a more engaging and structured way, which is crucial for understanding science concepts.

Research conducted by Khoiruddin & Iskandar (2024) shows that gamified learning media is not only considered highly feasible by media experts, content experts, and linguists but also proven effective in improving student learning outcomes. These results further strengthen the authors' commitment to developing this gamified learning media to its full potential. Although the effectiveness of gamification has been widely discussed in international literature, there remains a research gap regarding the development of gamification media specifically for energy transformation in rural elementary schools, which face limited device availability but high technological demands. Most previous studies have focused on pure gaming platforms, which tend to require high-end hardware specifications and specialized programming skills. The use of Canva as a gamification platform easily accessible to classroom teachers has rarely been explored in depth, particularly in the context of its effectiveness on science learning outcomes and science studies, which are specific to certain geographic regions. This research aims to fill this gap by developing a gamification learning medium called "Si Pegi."

This research is significant in bridging teachers' limitations in technology mastery through the use of user-friendly platforms like Canva. The primary objective of this study is to develop and test the effectiveness of the gamification learning medium "Si Pegi" in improving science learning outcomes in fourth-grade elementary school students. The research's primary contribution lies in providing a learning media design that adapts to diverse learning styles while transforming abstract material into an educational playful experience. Furthermore, this research contributes to the educational literature by demonstrating how game elements can be organically integrated into the Independent Curriculum (Curriculum Mandiri) to strengthen science learning outcomes.

Therefore, this research is expected to not only provide theoretical contributions to the development of educational science, but also transform learning to be more engaging and personalized, while also serving as a strategic tool to bridge abstract conceptual understanding into more concrete ones. This research also provides practical solutions for teachers in integrating technology into the classroom to optimize science learning outcomes in elementary schools.

METHODS

This study employed a research and development (R&D) approach aimed at developing and validating the gamified learning media "Si Pegi." The R&D method was chosen in this context because it allows researchers to systematically design, produce, and disseminate educational products to improve the effectiveness of learning outcomes in a real-life classroom environment (Sugiyono, 2014). Epistemologically, this development model is based on a constructivist perspective, where the validity of an educational product is tested through its functional effectiveness in solving classroom learning

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problems and students' ability to construct knowledge independently through interaction with the media (Febriani, 2021).

The product developed in this study is an interactive learning media based on the Canva application, integrating gamification elements into the material on Energy Transformation in the science subject. The development process follows the 4D model procedure, which consists of four main stages: define, design, develop, and disseminate.

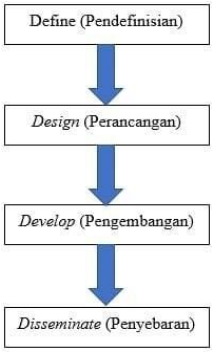

Figure 1. 4D Development Model

In the define stage, teacher and student needs analysis, student characteristics analysis, and material analysis were conducted. The design stage included the development of an In-Depth Learning Plan (RPM), the design of the "Si Pegi" gamification learning media, and the development of validation, practicality, and effectiveness instruments. The develop stage focused on expert validation testing and user testing for practicality and effectiveness. Finally, the dissemination stage involved socialization and implementation of the media within a broader classroom setting.

The subjects of this study were fourth-grade students at SDN 11 Sitiung, the primary research site, and fourth-grade students at SDN 10 Sitiung, during the dissemination stage. A total of 36 students participated. Purposive sampling was used to ensure consistency of subject characteristics, as all fourth-grade students at both schools had similar initial abilities and followed the same curriculum. During the validation process, the researchers involved experts to assess the product's feasibility, including media expert validators, language experts, material experts, and experts who validated the in-depth learning plan and test instrument validation. Validation was conducted comprehensively using standardized assessment instruments. Media experts assessed visual aspects and interactivity, language experts assessed the accuracy of diction and text comprehensibility according to the cognitive development of elementary school students, and material experts assessed the depth of content. In addition, fourth-grade teachers also participated as practitioners to evaluate the practicality of implementing the media in the classroom.

Data in this study were collected through several primary instruments, including validation sheets, practicality questionnaires, learning outcome tests, and documentation. The validation sheets were used to obtain product quality assessments from experts, covering aspects of media, language, materials, RPM, and test instruments. Meanwhile, practicality questionnaires were distributed to teachers and students to measure ease of use and appeal of the media. To measure effectiveness, learning outcome tests were used to assess improvements in students' cognitive understanding after implementing the "Si Pegi" gamification learning media. All instruments underwent academic validity and reliability testing to ensure accuracy and consistency in measuring each research variable. Subject responses in the questionnaires were measured using a structured Likert scale.

To determine the level of validity and practicality of the media, researchers used a percentage formula that compares the obtained score with the maximum score. The assessment criteria were divided into several intervals to determine whether the product fell into the category of very valid/practical to invalid/practical. In addition, the effectiveness of the media was also reviewed based on the Learning Objective Achievement Criteria (KKTP) to determine intervention or enrichment steps for students. Data analysis was conducted using a combination of qualitative and quantitative descriptive techniques. Qualitative data derived from validator suggestions were analyzed to improve the media, while quantitative data from the questionnaire were processed using descriptive statistics to determine the percentage of validity and practicality. Finally, the level of effectiveness was

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measured through the percentage of completion of classical learning outcomes. Through this series of procedures, the study can conclude the overall feasibility of the "Si Pegi" gamification learning media in optimizing science learning outcomes (IPAS) in elementary schools.

Table 1. Likert Scale Scoring (Validity and Practicality)

Score	Category
1	Disagree (ST)
2	Somewhat Disagree (KS)
3	Somewhat Agree (CS)
4	Agree (S)
5	Strongly Agree (SS)

To measure the level of validity or practicality, researchers use the following formula:

$$V/P = \frac{f}{n} \times 100\%$$

Where:

V = Validity level
P = Practicality level
F = Score obtained
N = Maximum score

Table 2. Criteria for Product Validity and Practicality

Interval (%)	Validity Category	Practicality Category
0 %≤ V/P < 20%	Very invalid	Very impractical
20 %< V/P ≤ 40%	Invalid	Not practical
40 %< V/P ≤ 60%	Somewhat valid	Quite practical
60 %< V/P ≤ 80%	Valid	Practical
80% < V/P ≤ 100%	Very valid	Very practical

Table 3. Criteria for Achieving Learning Objectives (KKTP)

Interval (%)	Validity Category	Practicality Category
0-40%	Not yet achieved the goal	Repair work in all areas
41-65%	Not yet achieved the goal	Repair work as needed
66-85%	Has achieved the goal	No repair work required
86-100%	Has achieved the goal	Requires enrichment

RESULTS

The results of this study indicate that the validation of the "Si Pegi" gamification learning media product developed through the Canva platform has passed a series of rigorous assessments by experts to ensure its technical quality, readability, and substantive accuracy. This media feasibility evaluation involved collaboration between validators across disciplines, including media experts, linguists, and material experts, as well as assessments of operational support tools such as the In-Depth Learning Plan (RPM) and evaluation instruments. Based on quantitative data analysis from the validation sheet, the "Si Pegi" gamification learning media obtained an overall average score of 94.66%, placing it in the "Very Valid" category. In detail, the media validator gave a score of 96% referring to the excellence of the visual aspects and navigation functionality. The language validator gave a score of 94% regarding the accuracy of diction for elementary school-aged children, and the material validator gave a score of 94% regarding the suitability of the content to the curriculum. In addition, the supporting tool in the form of the RPM achieved a score of 92.21% and the question instrument received a score of 89.99%. These findings confirm that the "Si Pegi" media meets very high standards of professionalism and academic quality, making it fully suitable for implementation in the fourth grade of SDN 11 elementary school.

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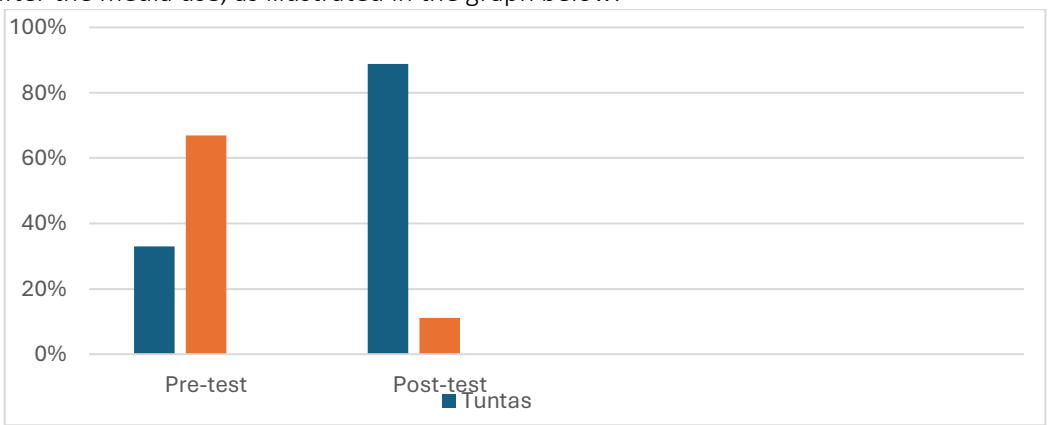
A practicality test was conducted to measure the ease of operation and aesthetic appeal of the media during use in the learning process. Practicality data showed an average RPM implementation score of 91.11%, categorized as "Very Practical." Interestingly, there was a significant increase in the third meeting, reaching 95%. This reflects that teachers and students have passed the technical adaptation phase and are beginning to demonstrate a stronger attachment to the gamification features. The subjective assessment from the fourth grade teacher gave a score of 90%, as the media was deemed capable of reducing the teacher's instructional load. Meanwhile, responses from 18 students yielded an average score of 89.91%, categorized as "Very Practical." The practicality of the "Si Pegi" gamification learning media, based on student responses, can be seen in the following table:

Table 4. Questionnaire Results Student Responses to the Gamification Learning Media "Si Pegi"

No.	Indicator	Percentage (%)
1	The use of language in the media is easy for me to understand.	85,55%
2	The material regarding changes in energy forms is presented in clear language.	94,44%
3	The guide to using gamification media was easy for me to follow.	90%
4	Gamification learning media is easy to use.	95,55%
5	I easily understand the material about changes in energy forms through this media.	90%
6	This media makes me more active in studying changes in energy forms.	90%
7	The learning sequence in this media is easy for me to follow.	86,66%
8	The colors in this medium are attractive and do not hurt my eyes.	88,88%
9	The design of the images and elements in this media are interesting.	86,66%
10	The font used is easy for me to read.	88,88%
11	The font size is large enough and appropriate, so it is easy to read.	90%
12	The use of gamification systems for rewards such as points and stars is very interesting and motivating for me.	90%
13	The image quality (resolution, clarity) used in the media looks clear and not blurry.	92,22%
	Average	89,91%

Cumulatively, the average practicality score for teacher and student responses reached 89.95%, indicating that the integration of interactive rewards, points, and challenges into the media successfully transformed the classroom atmosphere, making it more lively, positively competitive, and enjoyable.

The effectiveness of the "Si Pegi" media was objectively measured through a student achievement test on energy transformation. Based on data analysis from the trial with fourth-grade students at SDN 11 Sitiung, the effectiveness percentage was 88.88%, categorized as "Effective." This effectiveness is clearly demonstrated by the significant improvement in student test scores before and after the media use, as illustrated in the graph below:



Graph 1. Student Test Results Before and After Using "Si Pegi" Media

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Based on the test results graph of fourth-grade students at SDN 11 Sitiung, a significant improvement in learning outcomes was seen before and after using the gamified learning media "Si Pegi" on the topic of energy transformation. In the pre-test, the majority of students had not achieved learning mastery, with approximately 67% failing to complete the task, while only 33% were successful. However, after the "Si Pegi" media treatment, a striking and positive change occurred in the post-test. The percentage of students meeting the completion criteria jumped sharply to approximately 88.88%, while the number of students failing to complete the task decreased drastically to only 11.11%. Therefore, the "Si Pegi" gamified learning media was declared effective in improving science learning outcomes for fourth-grade elementary school students.

After the product proved effective in improving student learning outcomes, it was distributed to fourth-grade students at SDN 10 Sitiung and achieved the same effectiveness score of 88.88%. This achievement is a strong indicator that the "Si Pegi" media not only serves as a supporting tool but is also capable of significantly improving students' conceptual understanding of science compared to previously used conventional methods. This 88.88% figure reflects that the majority of students have exceeded the minimum learning completion threshold.

DISCUSSION

The initial goal of developing the "Si Pegi" gamified learning media was to produce a product that was not only visually superior but also effective in improving the science learning outcomes of fourth-grade elementary school students. The validation results, which reached an average of 94.66%, categorized as "highly valid," empirically demonstrated that this goal had been achieved. This achievement demonstrated a strong integration between visual aspects (96%), language (94%), materials (94%), and supporting tools such as the RPM (92.21%) and evaluation instruments (89.99%).

Scientifically, the media's high validity score (96%) indicates that the interface design, layout, and navigation system of "Si Pegi" successfully reduced extraneous cognitive load on students. In cognitive psychology, clear visual presentation and intuitive navigation are crucial to ensuring that fourth-grade elementary school students' working memory is fully allocated to processing the lesson content, rather than being consumed by understanding how to operate the system (Adeyele, 2024). The validation of the language (94%) and materials (94%) also provides a theoretical basis for the media's instructional narrative adapted to Piaget's concrete operations stage of cognitive development. By adapting word choice to minimize ambiguity, abstract material such as "energy transformation" can be contextualized into meaningful information for elementary school-aged children.

The high score of supporting instruments, such as the RPM (92.21%), distinguishes this study from previous development research trends. The feasibility of the RPM ensures that this gamification medium does not exist as an isolated entity within the classroom, but is systematically structured within a directed learning syntax. The synchronization between teaching tools and game features ensures that each play activity in "Si Pegi" always has a clear learning objective (Diab et al., 2024). This finding is consistent with and extends the theory of Dehghanzadeh et al., (2022), who stated that narrative structure and instant feedback in gamification are key foundations for successful knowledge transfer in elementary education.

The practicality measurement of "Si Pegi" yielded a score of 89.95%, categorized as "very practical," supported by the RPM implementation rate of 91.11% and positive student responses of 89.91%. These data indicate a high level of practicality of the product in the field and the ease of its technical burden for teachers during the teaching process.

Importantly, an interesting dynamic was observed in the increase in RPM implementation, reaching 95% by the third session. This phenomenon can be analyzed through the lens of the Technology Acceptance Model (TAM), where levels of ease of use and usability increase linearly as users adapt (Lai et al., 2023). In the initial phase, teachers and students needed time to technically synchronize the rules and reward mechanisms. However, once the game's pattern was understood, procedural barriers significantly reduced, resulting in significantly more efficient teacher time management in the classroom. This characteristic aligns with the principles of interactive digital

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media, which state that classroom efficiency increases with the accumulation of repeated user experience (Kalogiannakis et al., 2021).

Furthermore, the high positive student response rate (89.91%) provides psychological insight into students' emotional attachment to gamification components (points, challenges, and rewards). The psychological characteristics of Generation Alpha, who grew up in a digital ecosystem, demand a learning environment that provides instant feedback and rich visual stimulation (Alotaibi, 2024). When game elements are implemented, students' intrinsic motivation is stimulated because they feel challenged while remaining in a safe learning space where they can experiment without fear of failure (Radil et al., 2023). This demonstrates that practicality extends beyond operational ease to emotional appeal, successfully shifting students' perceptions of science lessons (IPAS) from theoretical to engaging, interactive adventures.

The effectiveness rating, which reached 88.88%, provides empirical confirmation that the "Si Pegi" media can have a real impact on improving students' cognitive learning outcomes on the topic of energy transformation. The finding that this effectiveness score was consistent across two schools, during the pilot at SDN 11 Sitiung and the dissemination phase at SDN 10 Sitiung, demonstrates a high level of product reliability and replicability when implemented in schools with comparable demographic characteristics.

This successful improvement in learning outcomes can be explained theoretically through a social constructivism framework. In the "Si Pegi" media, students are positioned not as passive (conventional) recipients of information, but rather as active agents constructing their own knowledge (Batdi, 2023). Through a visual learning flow that progresses from simple to complex levels, abstract scientific concepts about energy are transformed into concrete and interactive forms. As students interact with the challenges, they are required to engage in assimilation and accommodation, connecting their prior knowledge to the energy transformation phenomena they encounter in the game (Aparicio-Ruiz et al., 2026).

This high level of effectiveness aligns with the findings of Oliveira et al (2022), who confirmed that game-based learning environments significantly improve students' cognitive retention in science. Furthermore, these findings reinforce a study by Maulidya & Astuti (2025), which stated that effective learning media must be able to stimulate students' interest and thinking to achieve learning objectives efficiently. The balanced integration of validity (theoretical feasibility), practicality (ease of implementation), and effectiveness (impact on outcomes) in "Si Pegi" demonstrates an important principle in development research: that educational innovation products must prioritize not only visual aesthetics but also be pedagogically sound to produce optimal learning outcomes (Kamalodeen et al., 2021).

This research on the development of the "Si Pegi" media provides a more specific contribution and offers novelty compared to previous gamification studies. In previous research, developers often focused solely on the visual aspects of the media, without understanding the readiness of learning scenarios in real classrooms (Baghaei et al., 2025). This research differentiates itself by integrating an In-Depth Learning Plan (RPM) designed to be fully synchronized with the features within the "Si Pegi" gamification learning media. This integration ensures harmony between the teacher's instructional steps in the classroom and the digital activities undertaken by students. The results of this study critically demonstrate that the alignment between conventional teaching tools (RPM) and modern gamification media is a key determinant of high levels of student learning completion.

In addition to device synchronization, the higher effectiveness results in this study are strongly suspected to be driven by the use of the iconic personal character "Si Pegi." The presence of a local mascot or mentor character in the game has been shown to psychologically build an emotional connection between students and the learning material (Vebrianto & Osman, 2021). This character acts as a bridge that reduces children's science learning anxiety, a dimension rarely explored in depth in other generic gamification research.

Theoretically, the results of this study make a significant contribution to strengthening constructivist learning theory and cognitive load theory in the context of the digitalization of elementary education. These findings challenge conventional wisdom by demonstrating that game elements (such as point systems and levels) are not distractions for children, but rather can serve as digital scaffolding that gradually guide their cognitive development (Lellis-Santos, 2026). This

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research expands the literature on interactive learning design, specifically addressing the learning characteristics of Generation Alpha.

Practically, these research findings provide tangible contributions that can be directly implemented by various parties within the education ecosystem. For elementary school educators, the gamified learning media "Si Pegi" can be adopted as an innovative alternative to the one-way lecture method in science and technology. Through the implementation of this media, teachers can shift teaching patterns to be more student-centered, which directly impacts the visualization of abstract energy transformation concepts into concrete concepts, thus optimally achieving students' cognitive learning outcomes.

For school principals and policymakers, the results of this study provide strong empirical data to reform the strategy and focus of teacher digital competency training. Teacher training should no longer focus solely on the technical skills of creating static presentation slides, but should also focus on managing gamification-based media, which has been proven effective in improving student cognitive retention and achievement of science content. Finally, for learning media developers, the success of this study underscores the importance of incorporating valid teaching aids, such as In-Depth Learning Plans (RPM), into every product they create. Synchronization between the systems within the media and these teaching aids is crucial to ensuring that the designed digital activities can be easily adopted in the classroom and systematically improve student academic learning outcomes.

Despite the positive results, this study has limitations that require consideration. The study sample was limited to two schools and one grade level, so generalizing the results to a broader context requires caution. Furthermore, the success of digital media implementation is also influenced by the availability of devices and internet connectivity in schools. These factors can become barriers if the media is implemented in learning environments with unequal technological facilities. Another limitation lies in the measurement focus, which is still dominated by the cognitive domain. However, gamification media also has the potential to influence affective aspects such as motivation, self-confidence, independent learning, and cooperation among students. Therefore, the results of this study could be further enhanced by more systematic observation of non-cognitive dimensions in future research.

Based on these results, further research could be directed at trials with a larger sample size and a wider variety of school characteristics. Further research could also compare the effectiveness of "Si Pegi" with other learning media to gain a more comprehensive picture of its advantages. Furthermore, future developments could include collaborative or reflective features so that the media not only stimulates cognitive learning outcomes but also fosters a more independent and active learning attitude.

Overall, the results of this study indicate that the "Si Pegi" gamification learning media is a valid, practical, and effective learning innovation for energy transformation material in fourth-grade elementary schools. Supported by engaging visual design, age-appropriate language, curriculum-aligned materials, and seamless RPM integration, this medium is worth considering as a more enjoyable and meaningful alternative for science learning.

CONCLUSION

Based on the results of research and development of the gamification learning media "Si Pegi" for the effectiveness of science learning outcomes (IPAS) in grade IV elementary schools, several main conclusions can be drawn. First, the product developed using the 4-D model (Define, Design, Develop, Disseminate) is categorized as "Very Feasible" based on expert validation with an overall average score of 94.66%. In detail, the media aspect obtained a score of 96%, the language aspect obtained a score of 94%, and the material aspect obtained a score of 94%, proving that this media has met technical standards, is in accordance with student cognitive development, and has strong conceptual accuracy. Second, the level of practicality of this media is rated "Very Practical" with an average accumulative response from teachers and students of 89.95%. This proves that "Si Pegi" is easy to operate, has intuitive navigation, and is able to help teachers in presenting science material that was previously considered abstract to be more concrete through gamification elements. Third, the media's effectiveness was significantly proven through improved student learning outcomes. The field trial at SDN 11 Sitiung yielded an effectiveness percentage of 88.88%, categorized as "Effective." This

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consistency of results was also evident during the dissemination phase at SDN 10 Sitiung, which demonstrated the same effectiveness rate of 88.88%. These findings confirm that the integration of game elements such as points, levels, and interactive challenges in the "Si Pegi" gamified learning media can improve student learning outcomes on the topic of energy transformation in fourth-grade elementary schools, in line with the primary research objectives.

In addition to these academic achievements, this research significantly contributes to the author's professional and pedagogical competencies. Through this research and development process, the author was able to deepen her theoretical understanding of technology integration in the elementary school curriculum, hone her practical skills in designing interactive gamification-based learning media, and develop her adaptability and innovation skills in facing the challenges of digital learning in the modern era.

Elementary school teachers are recommended to begin integrating gamification-based media into science lessons to visualize abstract science concepts and create a more immersive learning experience for students. Furthermore, schools are expected to provide strategic support by providing adequate digital devices and infrastructure to optimize the use of interactive learning media in the classroom. Finally, future researchers are advised to expand the scope of the material and its implementation to different grade levels. In addition, research development can be directed at experimental studies with control groups to measure the influence of gamification media more specifically on other competency variables, such as students' critical thinking skills, creativity, and digital literacy.

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CONFLICT OF INTEREST

The authors confirm that they have no conflicts of interest related to the publication of this study. They have no financial, personal, or professional interests that could be perceived as influencing the research outcomes or interpretations presented in this publication.

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