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Development of GENSEN interactive media using PjBL-STEM to improve elementary science literacy

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Abstract

Learning activities in Science and Social Studies (IPAS) regarding energy source material at the elementary school level are generally still implemented using traditional instructional approaches, characterized by a heavy reliance on textbook-based lectures and limited integration of interactive digital media. Consequently, students' scientific literacy and critical thinking abilities have not yet developed optimally, as learning tends to focus on the passive delivery of factual knowledge rather than encouraging students to explore concepts actively and apply them in real-life contexts. This condition indicates an urgent need for instructional innovation that aligns with the demands of 21st-century education. In response to this gap, the present study was conducted to design and evaluate the effectiveness of GENSEN, a Genially-based interactive media integrated with the STEM-oriented Project-Based Learning (PjBL-STEM) model. Adopting a Research and Development (R&D) approach using the ADDIE framework, this study involved 38 fourth-grade students in a pre-experimental one-group pretest-posttest design. Data were collected through scientific literacy assessments, classroom observations, and semi-structured interviews. Quantitative analysis using a paired sample t-test demonstrated a statistically significant improvement in students' scientific literacy ($p < 0.001$), with the mean score increasing substantially from 51.5 on the pretest to 88.6 on the posttest. Furthermore, the effectiveness of the intervention was confirmed by a normalized gain (N-Gain) score of 0.76, placing the improvement in the "High" category. The results showed that GENSEN media is highly practical, with teacher response scores reaching 92.5% and student responses at 87.9%, both falling into the 'Very Practical' category. Overall, these findings suggest that genially interactive media integrated with PjBL-STEM effectively supports conceptual understanding, fosters critical thinking, and promotes active participation. Consequently, this media represents a promising innovative alternative for contextual IPAS instruction in elementary education.

Keywords: *Interactive Media; Genially; Project-Based Learning; STEM; Scientific Literacy.*

INTRODUCTION

Education in the twenty-first century has undergone a fundamental paradigm shift, moving away from the traditional rote-memorization models that once dominated classrooms toward the development of dynamic, applicable competencies (Ajuoga & Odhiambo, 2023). This transformation is driven by a globalized landscape that compresses geographical boundaries and a technological surge that disrupts industries overnight, fundamentally altering the qualifications students need to thrive. As argued by Abdul et al. (2023), the focus of educational instruction must now reside in high-level critical thinking and complex problem-solving. Relying solely on the memorization of facts renders a student's knowledge obsolete almost immediately in the face of constant innovation. Without a pedagogical framework that enables learners to adapt flexibly to novel situations, students risk remaining trapped in outdated paradigms that fail to address the intricacies of contemporary life (Suyono et al., 2025).

Furthermore, mastering these twenty-first-century competencies is not merely a short-term academic milestone; it serves as the essential foundation for a student's lifelong personal and professional journey. Analytical reasoning allows individuals to unpack complex global issues-ranging from public health crises to economic shifts-with scientific precision (Winarni et al., 2022). Transforming schools from simple information repositories into launchpads for creativity is particularly vital during the elementary years. It is in these formative stages that cognitive habits and learning behaviors take their first permanent shape. Early investment in these capabilities creates a compounding effect on long-term outcomes (Zakarina et al., 2024). Nations that fail to prioritize these skills risk a permanent disadvantage in the global competition for human capital, whereas forward-thinking countries have systematically integrated scientific literacy into their national curricula as a strategic investment (Kain et al., 2024).

Within the domain of Natural and Social Sciences (IPAS), scientific literacy emerges as an irreplaceable cognitive priority. It demands that students go beyond abstract scientific concepts to connect their knowledge with everyday phenomena in meaningful ways (Toharudin et al., 2023). Through an inquiry-based approach, learners are encouraged to cultivate a sense of wonder about natural patterns, ultimately fostering the mindset of a lifelong learner (Utomo et al., 2023). Thinking scientifically trains students to evaluate information based on solid empirical evidence-a skill that has become vital in an era characterized by information overload and unfounded claims (Sari et al., 2024). The primary challenge in elementary science education is transitioning students from passive recipients of data into active investigators who can formulate questions, gather evidence, and draw conclusions through rigorous scientific procedures (Masithah et al., 2022).

Despite these global ideals, empirical reality in Indonesia reveals a staggering gap between expectations and actual student achievement. This systemic challenge is starkly reflected in international assessments such as PISA 2022, where Indonesia recorded a science score of only 396-well below the OECD average of 485 points (OECD, 2019). Ranking in the lower quartile of eighty-one participating nations signals an urgent need for pedagogical reform. This is further corroborated by PISA for Schools 2024 data, which highlights a concerning trend: the majority of Indonesian elementary students struggle with fundamental energy concepts, including the classification of energy sources and their transformation processes (Ayu et al., 2025). Domestically, the 2023 National Assessment (*Asesmen Nasional*) conducted by Kemendikbudristek confirms this pattern; while students may perform adequately on simple recall tasks, their performance plummets when faced with analytical tasks requiring conceptual integration and data interpretation (Nugroho et al., 2024).

This deficit in scientific literacy is vividly observable at the grassroots level, specifically at SDN Kendalasem. Initial observations conducted by the researcher at this institution revealed that the IPAS learning process remains heavily dominated by teacher-centered, conventional methods. Students are typically relegated to listening to textbook-based lectures without engaging in deep exploration. Consequently, scientific literacy at SDN Kendalasem remains low, particularly regarding the topic of energy sources and transformations, which are inherently abstract.

Furthermore, a significant practical gap was identified: teachers face difficulties in accessing instructional media that are not only innovative but also user-friendly and efficient to implement within limited classroom hours. The absence of "ready-to-use" interactive tools that align with the curriculum makes it challenging for educators to facilitate complex learning models like PjBL-STEM. Students frequently struggle to distinguish between various forms of energy or explain how energy changes in daily life. The lack of interactive and varied learning media at the school has led to a decline in student motivation, with science being perceived as a mere collection of definitions to be memorized for exams rather than a tool for understanding the universe.

Theoretically, the literacy gap at SDN Kendalasem can be analyzed through the lens of Bloom's Taxonomy, which suggests that classroom activities are largely locked in Lower Order Thinking Skills (LOTS) (Rivas et al., 2025). However, another critical factor contributing to this failure is the excessive cognitive burden placed on students. According to Cognitive Load Theory (CLT), when elementary students are forced to process abstract information about energy transformations solely through dense, static text, their working memory becomes overloaded (*extraneous load*) (Evans et al., 2024). This prevents the construction of meaningful mental models. Therefore, the development of GENSEN media specifically applies CLT principles by utilizing Genially's intuitive navigation and dynamic visual representations to minimize extraneous load, allowing students to focus their limited cognitive capacity on essential scientific concepts (Azizatunnisa et al., 2022).

To address these localized problems at SDN Kendalasem, the integration of the Project-Based Learning (PjBL) model combined with the STEM (*Science, Technology, Engineering, and Mathematics*) approach offers a more authentic framework (Sujud et al., 2024). PjBL involves students in sustained investigations of real-world problems, while the STEM approach ensures disciplinary rigor (Retno et al., 2025). However, the effectiveness of PjBL-STEM in elementary schools is highly dependent on learning media that can bridge the gap between abstract thought and physical activity (Salve & Chavhan, 2022). This is where the Genially platform serves as a crucial digital instrument. Genially enables the development of manipulative content where abstract energy transformations can be visualized through dynamic animations, acting as "cognitive scaffolding" within the Zone of Proximal Development (ZPD) as theorized by Vygotsky (Diana et al., 2021).

Previous research in the field of elementary science education has introduced various digital interventions, ranging from static PowerPoint presentations to passive educational videos and simple drill-and-practice applications. While these tools offer a departure from traditional textbooks, they often suffer from significant pedagogical limitations. Static media fail to provide the cognitive scaffolding necessary for visualizing abstract energy transformations, often trapping students in a passive viewing role that does not stimulate higher-order thinking (HOTS-oriented) (Khairi et al., 2022). Furthermore, many existing platforms lack a structured inquiry framework, treating digital content as a mere repository of information rather than a manipulative environment for scientific exploration (Nurhasanah et al., 2025).

Moreover, the integration of PjBL-STEM in existing media often remains fragmented; some tools focus solely on the 'technology' aspect without providing the 'engineering' or 'project' trajectory required for authentic learning. Conventional physical teaching aids, on the other hand, are often limited by logistical constraints and cannot simulate complex, invisible energy flows as effectively as digital simulations. GENSEN addresses these critical gaps by transforming the digital interface from a passive display into an active, STEM-oriented workspace. Unlike its predecessors, GENSEN does not merely present content; it facilitates the entire PjBL-STEM cycle-from problem identification to project design-within a single, non-linear interactive environment, making it a distinct and urgent necessity for modern IPAS instruction.

This study positions itself to fill the practical gap at SDN Kendalasem through the development of GENSEN (*Game Edukatif Sumber Energi*) interactive media. The novelty of this study does not merely lie in combining Genially with the PjBL-STEM approach, but in constructing a theoretically aligned pedagogical framework where process (PjBL), interdisciplinary context (STEM), and interactive multimodal representation (Genially) operate synergistically. This research is designed to meet the criteria of a high-quality instructional product, focusing on three essential dimensions: validity (theoretical soundness), practicality (ease of use for teachers and students), and effectiveness (impact on learning outcomes). PjBL activates inquiry and collaborative knowledge construction, STEM contextualizes scientific concepts within authentic real-world problems, while genially functions as a cognitive scaffolding environment that visualizes abstract energy transformations and embeds formative literacy assessment. This alignment generates an integrated epistemic learning environment that simultaneously stimulates conceptual understanding, evidence-based reasoning, and scientific communication-core dimensions of scientific literacy (Widiyono et al., 2025).

Focusing on the topic of energy sources and transformations in the fourth grade at SDN Kendalasem, this study is guided by three primary objectives: to evaluate the theoretical validity of GENSEN media, to assess its practicality from the perspective of teachers and students, and to measure the extent to which this Genially-based PjBL-STEM media improves students' scientific literacy. The research hypotheses predict that this intervention will yield statistically significant improvements in scientific literacy compared to traditional methods. Ultimately, this research aims to provide both a theoretical contribution to the literature on digital learning media and a practical solution for teachers at SDN Kendalasem and similar schools, ensuring that the next generation is scientifically equipped to contribute to global progress.

RESEARCH METHODS

Participants

The participants in this research were 4th-grade students at SDN Kendalasem, Demak Regency, during the first semester of the 2025/2026 academic year. The study utilized a total sampling technique (saturated sample), involving all 38 students (18 males and 20 females). This demographic was selected because the IPAS curriculum for grade 4 specifically covers energy sources and transformations, and the students' developmental stage-transitioning from concrete to formal operational thinking-requires multimodal and interactive stimuli to grasp abstract concepts.

Research Design and Procedures

This study employed a Research and Development (R&D) approach using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) framework (Muthmainnah, 2025). The research design used in this study was a pre-experimental design with a one-group pretest-posttest model was utilized to measure the effectiveness of the intervention.

It is important to note that the use of a single-group design at one specific school carries limitations in terms of broad generalization. Consequently, this study is framed as a localized case study focused on the effectiveness of the GENSEN intervention within the specific context of SDN Kendalasem, rather than a universal claim for all elementary populations.

The procedures followed these five sequential stages:

1. Analysis

   Identifying literacy gaps and digital resource limitations through teacher interviews and classroom observations at SDN Kendalasem.
2. Design

   Formulating learning objectives based on the *Kurikulum Merdeka* guidelines. The design principle focused on Cognitive Load Theory (CLT), ensuring that the Genially interface minimized extraneous load through intuitive navigation.
3. Development

   Constructing the GENSEN media by integrating PjBL-STEM components, including scientific content on energy and digital interactivity.
4. Implementation

   Deploying the media over four sessions, including a pretest, PjBL-STEM activities using GENSEN, and a posttest.
5. Evaluation

   Assessing media feasibility through expert validation and measuring literacy gains via N-Gain analysis.

Instruments

The rigorous collection of data in this study was facilitated through a multifaceted set of instruments, encompassing both test and non-test formats to ensure comprehensive triangulation of the findings.

1. Scientific Literacy Test Validation

   To measure the primary variable, a Scientific Literacy Test consisting of 20 multiple-choice items was developed, aligned with the *Kurikulum Merdeka* Learning Outcomes for 4th-grade IPAS. To meet the rigorous standards of instrument validity required for academic research, the test underwent a two-stage validation process. First, content validity was established through Expert Judgment involving two senior science education specialists who evaluated the items based on a structured table of specifications (blueprints) covering C3, C4, and C5 Bloom's levels (Heller, 2022).

Second, the instrument underwent empirical validation via a pilot test conducted with 5th-grade students at SDN Kendalasem. This group was selected because they had already completed the energy source curriculum, ensuring the data reflected the instrument's quality rather than the students' initial learning process. The empirical data were analyzed using the Point-Biserial Correlation to determine item validity, ensuring all items reached a significant correlation coefficient ($r_{Pbi} > r_{table}$)(Sibar et al., 2025). Furthermore, the instrument's internal consistency was verified using Cronbach's Alpha, yielding a coefficient of 0.74, which exceeds the 0.70 threshold, confirming that the test is highly reliable for measuring scientific literacy.

2. Expert Validation Protocols (Media Feasibility)

The technical and pedagogical quality of the GENSEN media was evaluated using two specialized validation protocols, both utilizing a 5-point Likert Scale (ranging from 1: "Very Poor" to 5: "Very Good"). The Subject Matter Expert Validation involved a detailed assessment of 24 items spanning six domains: curriculum alignment, developmental suitability, depth of content, illustration effectiveness, linguistic clarity, and the systematic structure of the embedded quizzes (Ariani et al., 2025). Complementing this, the Media Expert Validation scrutinized 20 items focusing on the digital experience, including visual consistency, navigation intuitiveness, cross-platform accessibility, and the technical responsiveness of the Genially interface (T. E. Siregar et al., 2024).

3. Practicality Instruments

To assess the ease of use and implementation of the media, the study employed Teacher and Student Response Questionnaires. These instruments utilized a 5-point Likert Scale (ranging from 1: "Strongly Disagree" to 5: "Strongly Agree") consisting of 12 items for each respondent group. The Teacher Response Questionnaire focused on four key aspects: ease of use, material consistency with the curriculum, efficiency in classroom time management, and the overall benefit of GENSEN in facilitating the PjBL-STEM model. Similarly, the Student Response Questionnaire measured three dimensions: usability (ease of navigation), attractiveness (visual engagement), and student involvement during the project-based activities. The results from these questionnaires provide quantitative evidence of the media's practical viability in a real-world classroom setting.

4. Qualitative Instruments

To capture the qualitative nuances of the classroom dynamic, the researcher employed a Classroom Observation Sheet and a semi-structured interview protocol (Ferdiani, 2025). The observation sheet featured 25 distinct indicators designed to monitor student behavioral engagement, specifically focusing on the 5C pillars: Critical Thinking, Collaboration, Communication, Creativity, and Concept Application (Nirmala et al., 2025). These observations were further enriched by teacher interviews to explore the practical shifts in student enthusiasm and digital accessibility once the GENSEN media was introduced. Together, these instruments provided a holistic view of the media's effectiveness in a real-world educational setting.

Data Analysis

The data collected in this study were analyzed using a combination of descriptive and inferential statistics to systematically the feasibility, practicality, and effectiveness of the GENSEN media. The first phase focused on product feasibility analysis based on validation data from subject matter and media experts. Scores obtained from the Likert-scale instruments were calculated as percentage scores (Robinson, 2023).These results were then interpreted against established eligibility criteria to determine whether the media met the requirements for field implementation or necessitated further refinement.

The second phase involved practicality analysis, derived from teacher and student response questionnaires. Similar to the feasibility analysis, the response scores were converted into percentages using the formula $P = \left(\frac{x}{n}\right)$ X 100% The results were then categorized based on Akbar's (2013) practicality criteria: 81-100% (Very Practical), 61-80% (Practical), 41-60% (Fairly Practical), and <40% (Impractical) (Akbar, 2017). This analysis was crucial to confirm the media's usability and engagement levels in a real classroom setting.

To test the hypothesis regarding the media's effectiveness in improving students' scientific literacy, a comparative analysis was conducted between pretest and posttest scores. Prior to inferential testing, a normality test was performed using the Shapiro-Wilk method to ensure the data distribution met parametric assumptions ($p > 0.05$). Once the normality prerequisite was confirmed, the analysis proceeded with a Paired Sample T-Test to determine the significance of the difference in students' competencies before and after the intervention.

The magnitude of improvement in students' scientific literacy was quantified using the Normalized Gain (N-Gain) formula (T. Siregar et al., 2025). This approach aimed to eliminate potential bias arising from variations in students' initial scores, allowing the intervention's effectiveness to be objectively categorized into low, medium, or high levels. Finally, all quantitative findings were triangulated with qualitative analysis following the Miles & Huberman model (Rusli et al., 2025), which involves data reduction, data display, and conclusion drawing. This qualitative integration provided a descriptive context regarding student behavior and engagement during the learning process, ensuring a holistic interpretation of the research outcomes.

RESULTS AND DISCUSSION

Result

The stages of ADDIE paradigm include Analysis, Design, Development, Implementation, and Evaluation that are applied in this research and development (R&D) project. The presentation of the study findings is systematically presented following these steps, which forms the development process of the PjBL-STEM-based GENSEN interactive learning materials.

1. Analysis Stage

The analysis step was done in IPAS classes whereby the learning requirements of primary school pupils were established and this was with reference to subject of energy sources. The interview and observation of the 4 th-grade teachers and their classrooms indicated that interactive learning materials were somewhat employed in teacher-centered learning practices that largely depended on textbooks and lectures. This situation rendered the students' passive and incapable of achieving an in-depth understanding of the concepts of energy sources, especially in terms of the aspects of scientific literacy such as the description of scientific events and the connection of the ideas to real-life circumstances.

Moreover, the analysis of the IPAS achievement scores of the student showed that some of them had not yet reached the minimum level of learning mastery of the subject on energy source. Evidently, some learning materials that can potentially engage students, contextualize the learning process, and foster the ability to think scientifically are required in the light of these findings. Therefore, the design of interactive learning resources based on the Genially platform and Project-Based Learning (PjBL-STEM) integrative of STEM was selected as an appropriate way of addressing these learning challenges.

2. Design Stage

Design phase was focused on the development of the GENSEN interactive media according to the findings of the requirements analysis. The learning objectives were clear and aimed at enhancing the scientific literacy level of the fourth-grade students in the content of the sources of energy. The energy source material was set to be compatible with the PjBL-STEM method. The GENSEN interactive media was created with the consideration of the interactivity preferences and the attractiveness of the pictures of primary school children in mind using the Genially platform. The flow of the learning, the position of the interactive elements, the animations, and the quizzes were all defined in the early storyboards and drawings of the media.

3. Development stage

The development stage aimed to transform the initial blueprints into a functional GENSEN interactive media prototype ready for classroom implementation. The feasibility of this product was measured quantitatively through expert validation scores and qualitatively through a systematic refinement process based on validator feedback. The feasibility score was calculated using the percentage formula: P= $\frac{\sum x}{\sum x}$ X 100% (Mayer, 2024). Based on this calculation, the media achieved significant validation scores: 98.5% from subject matter experts and 94.5% from media experts. These results place the GENSEN media in the "Very Feasible" category, confirming its suitability for primary school instruction (Budiastini et al., 2022).

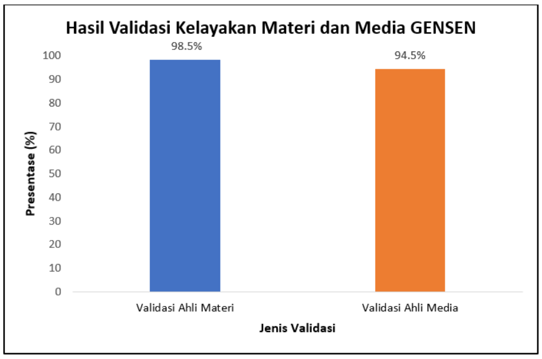

Figure 1.
Results of Material and Media Expert Validation of GENSEN

These high scores were not the result of a single-stage evaluation but were achieved through an iterative development and refinement process. While the subject matter experts stated that the content was highly comprehensive and required no further revision, the media experts provided several crucial technical recommendations. Their feedback primarily focused on strengthening the product's identity and improving student navigation. In response to these suggestions, the researchers revised the media interface by incorporating the official logo and the title "GENSEN (Game Edukatif Sumber Energi)" on the cover and main dashboard to reinforce the product's identity. Furthermore, the navigation system was enhanced by relocating and unifying the "User Guide" icon to a consistent position-the top left corner of every main page-ensuring it is easily accessible for young learners.

This revision process is a cornerstone of R&D research, as it demonstrates that the product's development is grounded in design ergonomics and user needs (students) rather than merely pursuing final validation figures (Omar et al., 2025). With these refinements complete, the GENSEN media is declared to have passed a rigorous validation phase and is prepared for the implementation stage to measure its effectiveness in enhancing students' scientific literacy.

Figure 2.
Main Interface of the GENSEN Interactive Learning Media

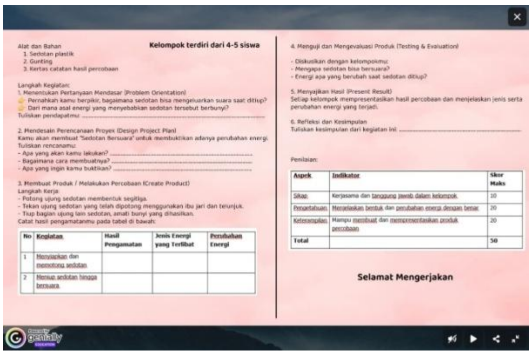

Figure 3.
PjBL–STEM Integrated Project Activity Screen

Figure 4.
Interactive Scientific Literacy Quiz Module

4. Implementation Stage

In the implementation phase, 38 fourth-grade primary students engaged with the PjBL-STEM framework and GENSEN interactive learning materials to study energy sources. At the commencement of the learning activities, students underwent a pretest to establish their baseline scientific literacy before interacting with the media. This initial assessment specifically evaluated their ability to explain scientific phenomena, their recall of fundamental scientific facts, and their capacity to apply energy-related principles to real-life situations.

The core learning process was subsequently carried out using the GENSEN media, which facilitates STEM-integrated project activities. Guided by the pretest results, students progressed through the project-based learning stages, starting from issue orientation and project design to conducting hands-on experiments. Throughout these stages, they presented their findings and engaged in collective reflection. The interactive features of the media-including digital research modules, group discussion prompts, and embedded quizzes-actively encouraged student participation and fostered a collaborative learning environment. To evaluate the practicality of the media during this phase, practicality data were collected through teacher and student response questionnaires administered immediately after the learning sessions. This allowed for an immediate assessment of the media's usability and engagement from the users' perspective.

Following the intervention, a posttest was administered using an identical assessment tool to determine the extent of improvement in students' scientific literacy. The effectiveness of the GENSEN medium in enhancing their understanding of energy sources was then rigorously evaluated by comparing the pretest and posttest outcomes. This comparative analysis served as the primary indicator of the media's success in meeting the research objectives.

5. Evaluation Stage

The aim of the assessment phase was to consider the whole process of the GENSEN media development and implementation with regard to the viability, practicality, and its impact on classroom teaching. The review was based on the results of the expert validation, teacher and student practicality responses, observations conducted during the course of the implementation, as well as improvement of the scientific literacy of the students after the medium usage.

Beyond effectiveness, the practicality of GENSEN was rigorously evaluated. The analysis of response questionnaires from two classroom teachers yielded a score of 92.5%, categorized as "Very Practical." Teachers noted that the media effectively streamlined the PjBL-STEM steps which are often difficult to manage manually. Furthermore, the response from 38 students reached a score of 87.9% ("Very Practical"), indicating high engagement with the interactive features and ease of navigation within the Genially interface.

Table 1.
Practicality Results of GENSEN Media

Respondent	Score Percentage	Category
Teachers (n=2)	92.5%	Very Practical
Students (n=38)	87.9%	Very Practical
Average	**90.2%**	**Very Practical**

There were also reflections on the application of interactive media-based project-based learning, namely how the students responded, how they engaged in the activities, and how the media was relevant to teaching IPAS in the primary school setting.

According to the findings of the conducted review the GENSEN interactive media was found to be considered valid, practical, and effective as an innovative educational instrument that enables the integration of contextual learning and development of primary school students' scientific literacy.

According to a descriptive analysis, the score of the scientific literacy of students improved after the application of the genially based interactive media with the PjBL-STEM method, which could be observed by comparing the results of the pretest and posttest. Pretest scores of the students prior to the intervention ranged between 31 and 69 and the average was 51.5. The average posttest score increased to 88.6 following the intervention with the range of 75 to 100. Table 2 is the pretest and posttest descriptive data of the students.

Table 2.
Descriptive Statistics of Students Pretest and Posttest Science Literacy Scores

Statistik	**Pre-test**	**Post-test**
Number of Students (N)	38	38
Mean	51.5	88.6
Median	50.0	88.0
Standard Deviation	10.0	6.28
Minimum Score	31	75
Maximum Score	69	100

Assumption testing had been done before further statistical analysis. The shapiro Wilk test was used to check the normality of the data. Table 3 showed that the posttest data were normally distributed ($p = 0.083$), which implies that the parametric test could be used. As the pretest and posttest scores were obtained based on a similar group of students, paired sample t-test was used to determine whether there was a statistically significant difference in the scores of the scientific literacy of the students before and after intervention.

Table 3.
Results of the Normality Test

			W	p
Pre-test	-	Post-test	0.949	0.083

The paired sample t-test results revealed a significant difference between pretest and posttest scores ($p < 0.001$), indicating that students scientific literacy scores increased after the implementation of the Genially-based interactive media integrated with the PjBL-STEM approach. The detailed results of the paired sample t-test are presented in Table 4.

Table 4.
Results of the Paired Sample t-test of Students Scientific Literacy

Mean Difference	**t**	**df**	**Sig.**	**95% CI Lower**	**95% CI Upper**	**Effect Size (d)**
37.1	27.0	37	<0.001	34.3	39.9	4.37

In addition, the effect size value was in the high category, indicating a substantial difference between pretest and posttest scores N-Gain analysis was also used to determine the magnitude of learning improvement. These outcomes revealed that the N-Gain value was 0.76 falling within high category as indicated in Table 5.

Table 5.
Results of N-Gain Analysis of Students Scientific Literacy

Mean Pretest	**Mean Postest**	**Skor Maksimal**	**N-Gain**	**Kriteria**
51.5	88.57895	43.8	0.769956	Tinggi

Discussion

The significant improvement in students' scientific literacy, as evidenced by an N-Gain score of 0.76, demonstrates that the GENSEN media is highly effective in facilitating the understanding of energy source concepts that were previously difficult to visualize. This effectiveness is inextricably linked to the media's high practicality, as shown by the teacher (92.5%) and student (87.9%) response scores. The high level of usability ensured that the technical aspects of the media did not hinder the learning process, allowing students to focus entirely on the scientific content. The use of this interactive media successfully bridged the gap between abstract concepts and concrete understanding, as indicated by the substantial difference between pretest and posttest scores. This success suggests that a Genially-based platform integrated with the PjBL-STEM framework can create a more meaningful, practical, and immersive learning environment for primary school students.

A more detailed analysis reveals that the most notable increase occurred in the indicator of "explaining scientific phenomena." This gain was primarily triggered by the synergy between the interactive content and the “LKPD” menu within the media. When students engaged in the *design a plan* stage of the PjBL-STEM syntax, the GENSEN media provided project guidelines accompanied by sequential illustrations of energy transformation. The practicality data from teachers (92.5%) confirmed that these digital guidelines significantly streamlined the project-based learning process, which is often perceived as time-consuming. This visualization helped students build accurate mental models of how energy changes from one form to another. According to Cognitive Load Theory (Sweller, 2011), such dynamic representation is far more effective than reading static text in printed books, as it significantly reduces extraneous cognitive load.

Furthermore, the "Interactive Quiz" element in GENSEN played a vital role in training students' precision and their ability to "interpret scientific evidence." Although the quiz utilized a straightforward feedback system-specifically indicating correct or incorrect answers-this mechanism challenged students to think more critically before selecting an answer to proceed with the navigation. Student responses (87.9%) highlighted that these interactive elements were the most engaging part of the media, fostering a sense of "digital play" that sustained their motivation throughout the STEM project. The active interaction between students and these digital elements aligns with the constructivist theory, wherein students independently construct their knowledge through interactive and participatory digital learning experiences (Fitria et al., 2021).

The "Very Practical" category achieved in this study also indicates that GENSEN addresses a crucial gap in teacher workload. With a 92.5% satisfaction rate, teachers reported that the media's intuitive interface reduced the need for constant technical troubleshooting, enabling them to act more effectively as facilitators during the PjBL-STEM stages. This synergy between practicality and effectiveness proves that for a digital tool to be successful in an elementary setting, it must be as easy to use as it is scientifically rigorous.

Despite these positive outcomes, this study acknowledges certain limitations due to its One-Group Pretest-Posttest (Pre-Experimental) design, which lacks a control group for comparison. This condition poses a threat to internal validity, as it remains difficult to definitively isolate whether the improvement in scientific literacy was derived solely from the GENSEN intervention or influenced by external factors during the learning process. Therefore, future research is encouraged to employ a Quasi-Experimental design involving a control group to more comprehensively test the effectiveness of the media and ensure stronger validity through rigorous inter-group comparison.

CONCLUSION

This study concludes that the GENSEN interactive learning media, integrated with the PjBL-STEM framework, is a highly valid, practical, and effective tool for enhancing the scientific literacy of fourth-grade elementary school students regarding energy sources. The media achieved a high practicality rating, with scores of 92.5% from teachers and 87.9% from students, indicating its ease of use and pedagogical relevance in primary education. The application of this media successfully transformed abstract scientific concepts into more concrete and engaging visual experiences, as evidenced by a significant increase in student scores and a high N-Gain of 0.76. The integration of STEM-based projects within the Genially platform enabled students to explore scientific phenomena actively and contextually, thereby fostering essential 21st-century skills such as critical thinking and problem-solving.

The findings contribute to the theoretical framework of interactive digital media in science education by providing a valid, practical, and effective alternative for teaching IPAS in primary schools. These results confirm that the synergy between PjBL-STEM and interactive multimedia can reduce students' cognitive burden while maintaining high learning engagement. However, since this research employed a Pre-Experimental (One-Group Pretest-Posttest) design, the results are limited by the absence of a control group. Therefore, it is recommended that future researchers utilize a Quasi-Experimental design with a broader sample size and a comparison group to further validate the effectiveness of GENSEN across diverse educational settings and more complex scientific topics.

REFERENCES

Abdul, B., Mantau, K., Talango, S. R., Sultan, I., & Gorontalo, A. (2023). Pengintegrasian Ketrampilan Abad 21 dalam Proses Pembelajaran (Literature Review). *Irfani: Jurnal Pendidikan Islam*, *19*, 86–107. https://doi.org/https://doi.org/10.30603/ir.v19i1.3897

Ajuoga, M. A., & Odhiambo, O. R. (2023). Prospects of the 21st Century Skills in Education: an implication for Competency Based Curriculum in Kenya. *International Journal of Research and Innovation in Social Science*, *VII*(XI), 1571–1581. https://doi.org/10.47772/IJRISS.2023.7011122

Akbar, S. (2017). *Instrumen Perangkat Pembelajaran*. Remaja Rosdakarya.

Ariani, D., Kartono, K., & Pranata, R. (2025). Pengembangan Tes Higher Order Thinking Skills (HOTS) untuk Mengukur Keterampilan Berpikir Peserta Didik Kelas IV SD. *YASIN*, *5*(5), 5295–5309. https://doi.org/10.58578/yasin.v5i5.7479

Ayu, G. N., Putri, C. A., Riyanto, A. R., & Koto, I. (2025). The Scientific Literacy Competence of Students in Indonesia and Mexico Based on PISA 2022: An International Comparative Study. *TOFEDU: The Future of Education Journal*, *4*(5), 1033–1038. https://doi.org/10.61445/tofedu.v4i5.525

Azizatunnisa, F., Sekaringtyas, T., & Hasanah, U. (2022). Pengembangan Media Pembelajaran Interaktif Game Edukatif Pada Pembelajaran IPA Kelas IV Sekolah Dasar. In *OPTIKA: Jurnal Pendidikan Fisika* (Vol. 6, Number 1). https://doi.org/https://doi.org/10.37478/optika.v6i1.1071

Budiastini, N. P. P., Astawan, I. G., & Widiana, I. W. W. (2022). Instrumen Multiliterasi pada Literasi Baca Tulis, Literasi Numerasi, dan Literasi Sains bagi Siswa Sekolah Dasar. *Mimbar Pendidikan Indonesia*, *3*(3), 357–367. https://doi.org/10.23887/mpi.v3i3.58894

Diana, N., Yohannes, & Sukma, Y. (2021). The effectiveness of implementing project-based learning (PjBL) model in STEM education: A literature review. *Journal of Physics: Conference Series*, *1882*(1). https://doi.org/10.1088/1742-6596/1882/1/012146

Evans, P., Vansteenkiste, M., Parker, P., Kingsford-Smith, A., & Zhou, S. (2024). Cognitive Load Theory and Its Relationships with Motivation: a Self-Determination Theory Perspective. *Educational Psychology Review 2024 36:1*, *36*(1), 7-. https://doi.org/10.1007/s10648-023-09841-2

Ferdiani, R. D. (2025). Optimizing Creative Thinking Skills Through STEM-PJBL: The Impact of Digital Modules. *Indonesian Journal of Educational Research and Review*, *8*(2), 313–325.

https://doi.org/10.23887/ijerr.v8i2.89707

Fitria, D., Jamaris, & Sufyarma. (2021). Implementation Of Constructivism Learning Theory in Science. *International Journal of Humanities Education and Social Sciences (IJHESS)*, *1*(3), 2808–1765. https://doi.org/10.55227/ijhess.v1i3.71

Heller, R. (2022). A new bloom – adding 'collaborate' to Bloom's taxonomy. *Journal of Learning Development in Higher Education*, (24). https://doi.org/10.47408/jldhe.vi24.906

Kain, C., Koschmieder, C., Matischek-Jauk, M., & Bergner, S. (2024). Mapping the landscape: A scoping review of 21st century skills literature in secondary education. *Teaching and Teacher Education*, *151*(4), 104739. https://doi.org/10.1016/j.tate.2024.104739

Khairi, A., Kohar, S., Widodo, H. K., Ghufron, M. A., Kamalludin, I., Prasetya, D., Prabowo, D. S., Setiawan, S., Syukron, A. A., & Anggraeni, D. (2022). *Teknologi Pembelajaran: Konsep dan Pengembangannya di Era Society 5.0*. PT. Nasya Expanding Management.

Masithah, I., Wahab Jufri, A., & Ramdani, A. (2022). Bahan Ajar IPA Berbasis Inkuiri Untuk Meningkatkan Literasi Sains. *Journal of Classroom Action Research*, *4*(2). https://doi.org/10.29303/jcar.v4i1.1758

Mayer, R. E. (2024). The Past, Present, and Future of the Cognitive Theory of Multimedia Learning. *Educational Psychology Review 2024 36:1*, *36*(1), 8-. https://doi.org/10.1007/s10648-023-09842-1

Muthmainnah, R. (2025). *Metodologi Penelitian Kualitatif, Kuantitatif dan RnD*. PT Tujuh Pustaka Penerbit.

Nirmala, W., Pratama, L., Tambunan, A. A., SN, U., Rahmawati, W., Rahman, M. H., Masta, P. K., Agus, C., Ainun, N. A., Umar, U., & Muda, F. P. (2025). *Metode Penelitian Kualitatif*. CV. Gita Lentera.

Nugroho, A. P., Iksan, R. N., Fitria, T. A., & Anne, Z. S. (2024). Renewable energy education and awareness among Indonesian students: Exploring challenges and opportunities for a sustainable future. *Sustainable Energy Technologies and Assessments*, *63*, 103631. https://doi.org/10.1016/j.seta.2024.103631

Nurhasanah, A., Handoyo, E., Widiyatmoko, A., & Rusdarti, R. (2025). Digital-Based Learning Media Innovation: Improving Motivation and Science Learning Outcomes. *International Journal on Social and Education Sciences*, *7*(2), 185–194. https://doi.org/10.46328/ijonses.723

OECD, O. (2019). *Social Impact Investment 2019 The Impact Imperative for Sustainable Development*. OECD.

Omar, M., Alsheky, A., & Faiz, B. (2025). Global Trends in Literacy and Science Skills: Analysis and Future Projections Based on PISA Data. *Journal of Pure & Applied Sciences*, *24*(3), 200–208. https://doi.org/10.51984/jopas.v24i3.4355

Retno, R. S., Purnomo, P., Hidayat, A., & Mashfufah, A. (2025). Conceptual framework design for STEM-integrated project-based learning (PjBL-STEM) for elementary schools. *Asian Education and Development Studies*, *14*(3), 579–604.

https://doi.org/10.1108/AEDS-08-2024-0188

Rivas, S. F., Bernardo, A. B., Casanova, J. R., & Saiz, C. (2025). Editorial: Educational transformation: 21st century skills and challenges for higher education. *Frontiers in Education*, *10*. https://doi.org/10.3389/feduc.2025.1583876

Robinson, J. (2023). Likert Scale. *Encyclopedia of Quality of Life and Well-Being Research*, 3917–3918. https://doi.org/10.1007/978-3-031-17299-1_1654

Rusli, A., Fadhil, M., Ishaq, M., Hidayatullah, R., & Harmonedi, H. (2025). Strategi Pengumpulan dan Pengelolaan Data dalam Penelitian Pendidikan: Kajian Teoretis dan Praktis. *IHSAN: Jurnal Pendidikan Islam*, *3*(3), 573–581. https://doi.org/10.61104/ihsan.v3i3.1045

Salve, S., & Chavhan, R. (2022). Project Based Learning For 21st Century. *ERJ: Educreator Research Journal*, *8*(4). https://doi.org/https://doi.org/10.5281/zenodo.7097047

Sari, L. S., Kaepah, K., Fitriani, P., Tresnawati, N., & Khodari, R. (2024). STEM Approach to 4C Skills in Elementary School Students: A Systematic Literature Review. *Scientiae Educatia*, *13*(1), 10. https://doi.org/10.24235/sc.educatia.v13i1.18062

Sibar, Nurhalimah., Shalihah, I., Raswan, R., & Ridlo, U. (2025). Uji Validitas Dan Reliabilitas. *Luxfia: Journal of Multidisciplinary Research*, *1*(1), 69–81. https://www.risetcendikia.com/index.php/journal-luxfia/article/view/131

Siregar, T., Abadi, A. M., Andayani, S., Rangkuti, A. N., & Sungkono, J. (2025). Uji Normalitas Gain untuk Pemantapan dan Modul Dengan One Group Pre and Post Test di SMP Negeri 1 Padangsidimpuan. *Dedikasi: Jurnal Pengabdian Kepada Masyarakat*, *3*(2), 499–504. https://doi.org/10.53276/dedikasi.v3i2.206

Siregar, T. E., Luali, N., Vinalistyosari, R. C., Hanurawan, F., & Anggraini, A. E. (2024). Implementation of Vygotsky's Constructivism Learning Theory through Project-Based Learning (PjBL) in Elementary Science Education. *Al Qalam: Jurnal Ilmiah Keagamaan Dan Kemasyarakatan*, *18*(4), 2586. https://doi.org/10.35931/aq.v18i4.3620

Sujud, R., Rahmawati, Y., & Utami, A. D. (2024). Development of Science Literacy Through Group Choice STEM-PjBL Projects Integrated with Matter State Changes. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2552–2564. https://doi.org/10.29303/jppipa.v10i5.6441

Suyono, Juwarlan, Prijo Harsono, Erwin Sutantyo, & Putranto, W. A. (2025). Critical Thinking And 21st-Century Skills: Evaluating the Effectiveness of Problem-Based Learning Models in Multicultural Classrooms. *International Journal of Educational Research Excellence (IJERE)*, *4*(2), 511–521. https://doi.org/10.55299/ijere.v4i2.1478

Sweller, J. (2011). Cognitive Load Theory. *Psychology of Learning and Motivation - Advances in Research and Theory*, *55*, 37–76. https://doi.org/10.1016/B978-0-12-387691-1.00002-8

Toharudin, U., Rahmiati, D., Fazriyah, N., & Hendrayana, S. (2023). *Literasi Sains: Pendekatan Pembelajaran Kontemporer*. PT. RAJAGRAFINDO PERSADA.

Utomo, E., Berbasis Proyek, P., Pengetahuan Alam, I., & Dasar, S. (2023). Constructivism Through Project-Based Learning Model on Natural Science Learning Subjects in Elementary Schools (Literature Review). *Primary: Jurnal Pendidikan Guru Sekolah Dasar*, *12*(4), 1055–1072. https://doi.org/10.33578/jpfkip.v12i4.9908

Widiyono, A., Nichla, S., Attalina, C., Zumrotun, E., Putri, L. A., & Lu'luatil Masturoh, L.'. (2025). PjBL-STEM-based Animal & Plants Metamorphosis Multimedia Innovation: Improving Students' Critical Thinking Skills in Elementary School. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *15*(1), 85–96. https://doi.org/10.30998/formatif.v15i1.26048

Winarni, E. W., Karpudewan, M., Karyadi, B., & Gumono, G. (2022). Integrated PjBL-STEM in Scientific Literacy and Environment Attitude for Elementary School. *Asian Journal of Education and Training*, *8*(2), 43–50. https://doi.org/10.20448/edu.v8i2.3873

Zakarina, U., Ramadya, A. D., Sudai, R., & Pattipeillohi, A. (2024). Integrasi Mata Pelajaran IPA dan IPS Dalam Kurikulum Merdeka Dalam Upaya Penguatan Literasi Sains dan Sosial Di Sekolah Dasar. *Damhil Education Journal*, *4*(1), 50. https://doi.org/https://doi.org/10.54297/seduj.v5i1.1215