Cendikia : Media Jurnal Ilmiah Pendidikan, 16 (6) (2026) pp. 412-420
Published by: IOCSCIENCE
Cendikia : Media Jurnal Ilmiah Pendidikan
Journal homepage: www.iocscience.org/ejournal/index.php/Cendikia

Alternative energy learning with STEM approaches to increase student's interest and creativity

Rahma Aisyah[1], Elly Sukmanasa[2], Didit Ardianto[3]
[1,2,3]Faculty of Teacher Training and Education, Pakuan University, Bogor, Indonesia

ARTICLE INFO

Article history:

Received Jun 25, 2026
Revised Jul 17, 2026
Accepted Jul 26, 2026

Keywords:

Alternative Energy
Elementary Science
Energy Transformation
Learning Interest
Student Creativity

ABSTRACT

Traditional elementary science instruction often relies on conventional teaching methods that inadequately contextualize abstract concepts, resulting in low student engagement, limited interest, and reduced creativity in learning energy transformation. This study proposes an integrated Science, Technology, Engineering, and Mathematics (STEM) approach adapted for fourth-grade students through a hands-on mini waterwheel project. A quasi-experimental pretest–posttest control group design was employed involving 50 students divided into an experimental group (integrated STEM) and a control group (standard Inquiry). Data were collected using learning achievement tests, questionnaires, and creativity assessment rubrics, and analyzed through independent sample t-tests and linear regression. The results demonstrate that the STEM approach significantly outperformed the conventional inquiry model in enhancing student creativity ($t = 4.454$, $p < 0.05$) and increasing learning interest. In addition, a strong positive correlation was identified between learning interest and creativity ($r = 0.694$), with learning interest contributing 73.3% to students' creative performance. These findings indicate that integrating STEM into elementary science instruction effectively transforms abstract scientific concepts into meaningful engineering experiences while fostering creativity and motivation. Therefore, the proposed instructional model provides a practical framework for elementary educators to systematically integrate interdisciplinary problem-solving into science learning, thereby promoting critical thinking, creativity, and adaptive skills from an early age.

Corresponding Author:

Rahma Aisyah,
Faculty of Teacher Training and Education,
Pakuan University,
Jl. Pakuan, Tegallega. Kecamatan Bogor Tengah Kota Bogor. Jawa Barat 16143, Indonesia
Email: rahmaaisyah23leo@gmail.com

INTRODUCTION

Basic education has a crucial role in building the foundation of students' scientific understanding, especially in Natural Sciences (IPA) subjects. Science learning at the elementary level aims to develop students' competencies in cognitive, affective, and psychomotor aspects, as stipulated in the 2013 Curriculum which emphasizes conceptual understanding as part of basic competencies in science learning (Rahardjanto & Susilowati, 2018). One of the fundamental learning outcomes in the fourth grade of elementary school is the mastery of the concept of energy transformation. The success of this learning process is highly dependent on several main endogenous variables, including cognitive learning outcomes, learning interests, and students' creativity (Widiyatmoko & Shimizu, 2018). When students have a high interest in science phenomena, they tend to be actively involved and show great curiosity. This positive emotional and cognitive involvement is the main fuel that triggers the emergence of students' creativity in finding solutions and understanding abstract concepts more deeply.

Theoretically, optimal learning outcomes, strong interests, and high creativity in elementary school students are integrated to form higher order thinking skills. Creativity in the context of elementary science is not just about creating something entirely new, but rather the ability of students to connect material concepts with real-life phenomena in unique ways (Murcia, 2008). When these aspects of learning outcomes, interests, and creativity develop in parallel, students are not only able to memorize formulas or operational definitions of energy, but also have long-term memory retention and good adaptability to face learning challenges at a higher level (Zaini et al., 2023).

Nevertheless, the reality on the ground often shows a significant gap from those ideal conditions. In energy transformation materials, the cognitive learning outcomes of elementary school students are often below the minimum standards of completeness (Azis et al., 2023). This low learning outcome is rooted in the lack of interest of students who consider science material as memorizing boring and theoretical formulas (Putra & Kumano, 2018). The implication is that the classroom becomes passive and students' creativity in exploring scientific ideas becomes hampered. The problem of low active involvement, interest, and creativity of students in understanding the concept of energy transformation is the main problem that is explicitly explained and solved in this study.

This gap is exacerbated by the dominance of conventional teacher-centered learning approaches. The conventional inquiry learning approach that is commonly applied often only stops at the conceptual stage on paper without providing a contextual practical experience for elementary school-age children (Jannah et al., 2025). Students are rarely given the opportunity to construct their own knowledge through real problem-solving activities. As a result, the potential for creativity that should have been stimulated early on dies, and science loses its appeal to students.

Several previous studies have extensively explored various methodologies to mitigate these pedagogical challenges in renewable energy education. For instance, initial efforts primarily focused on utilizing standardized inquiry frameworks or basic simulation software to illustrate energy transitions (Jannah et al., 2025) (Azis et al., 2023). However, a critical review of this existing literature reveals two fundamental limitations. First, previous interventions predominantly target secondary and higher education cohorts, leaving a noticeable empirical void regarding how these abstract frameworks can be socio-cognitively adapted for early childhood operations (Dossymov et al., 2026; Putra & Kumano, 2018). Second, and more importantly, prior research treats Science, Technology, Engineering, and Mathematics as isolated disciplinary silos or limits their integration to theoretical simulations rather than physical manipulation (Dossymov et al., 2026). Consequently, while past studies report short-term improvements in conceptual recall, they consistently fail to demonstrate a sustained growth in intrinsic interest and high-order creative reasoning due to the lack of tangible, hands-on engineering challenges. This dynamic constitutes the critical research gap that the current study addresses

To overcome these problems, this study proposes the application of an integrated Science, Technology, Engineering, and Mathematics (STEM) approach. Based on the theory of social constructivism, the STEM approach integrates four disciplines holistically to guide students to complete real-world problem-based projects (Ramaila, 2026). The concrete solution provided in this study is through the design of a mini waterwheel electric generator project. Through this method, students are actively challenged to analyze the science of water flow (Science), use measuring instruments (Technology), design the structure of the wheel (Engineering), and calculate the efficiency of the rotation of the wheel (Mathematics).

The distinct novelty of this study lies in its design of a fully integrated, physical STEM framework specifically engineered for fourth-grade elementary students using a low-cost, manipulative mini waterwheel model. Distinct from previous literature that relies on uniform instructions or purely digital environments, this framework shifts the operational focus toward a socio-cognitive learning environment where elementary students autonomously direct structural engineering and efficiency calculations. Furthermore, this study breaks new empirical ground by providing a robust quantitative analysis that models the precise correlation and exact percentage contribution of student interest toward distinct components of scientific creativity (fluency, flexibility, originality, and elaboration) using a rigorous quasi-experimental framework.

Therefore, the primary objective of this research is to investigate the efficacy of the integrated STEM approach in enhancing cognitive interest and problem-solving creativity among elementary school students during alternative energy instruction. By assessing these relationships, this study establishes a strong theoretical justification for replacing passive instructional methods with active, multi-disciplinary engineering practices in primary classrooms.

The impacts and value of the solutions offered in this study are not only limited to significantly improving cognitive learning outcomes, which is evidenced by the achievement of a high normalized gain score. More than that, this mini watermill STEM project-based learning innovation has a transformative impact on increasing students' interest and creative skills that are empirically measured. With a long-term impact, this study provides a practical new instructional model for elementary school educators across disciplines to contextualize abstract science material into simple engineering activities that are fun and meaningful

RESEARCH METHODOLOGY

This study applies a quantitative approach with a quasi-experimental design through a Pretest-Posttest Control Group Design. The research was carried out at SD Negeri Ciheuleut 2 Bogor City in the even semester of the 2025/2026 school year, precisely from May to June 2026. The study population included all grade IV students, with sampling techniques using purposive sampling based on the availability of homogeneous parallel classes. The research sample amounted to 50 students who were divided into two groups: class IV B (N = 25) as an experimental group that received the treatment of learning alternative energy materials with a Science, Technology, Engineering, and Mathematics (STEM) approach, and class IV C (N = 25) as a control group that was learned using the conventional Inquiry model. The acquisition of student learning interest data was measured using a Likert scale questionnaire instrument that included indicators of interest (science, mathematics, engineering, technology) and STEM career interest (Syamra & Suryadi, 2025).

To precisely operationalize the evaluation of student creativity as established in the study's stated novelty, a specialized mini waterwheel product performance assessment sheet was deployed. Rather than evaluating the final product solely on functionality, this instrument was explicitly structured around four core rubrics of scientific creativity defined by(Said-Metwaly et al., 2021). Fluency (the total number of relevant ideas generated during the structural engineering phase), flexibility (the shift across operational approaches when designing the wheel structure), originality (the uniqueness of the low-cost material combinations used), and elaboration (the detailed execution and optimization of the wheel's rotation efficiency calculation).

The validity of the instrument was tested using Biserial Point Correlations, while the reliability of the test instrument was calculated using the Richardson Quartet formula (KR-20) (Vivian Wong Shao Yun et al., 2023) which results in a very high reliability coefficient of 0.90. Data analysis to measure increased interest and creativity using normalized N-Gain formula (Sriyansyah & Azhari, 2017). The analysis prerequisite testing includes data normality testing using the Liliefors method and variance homogeneity test using the Fisher test. Finally, hypothesis testing was carried out using two-way t-test analysis at a significance level of 5% (α = 0.05) to evaluate the effect of the application of STEM approaches on students' interest and creativity.

Following the prerequisite checks, inferential statistical analyses were structured in a two-fold manner to address the primary objectives. First, a two-way independent sample t-test was executed at a significance level of 5% (alpha = 0.05) to evaluate the comparative effect and prove the operational efficacy of the integrated STEM framework against the conventional Inquiry model. Second, to address the empirical gap regarding the socio-cognitive dynamics between the two endogenous variables, a simple linear regression analysis was integrated into the workflow. This specific regression model was utilized to calculate the exact coefficient of determination (R^2), thereby isolating and determining the precise percentage contribution of student learning interest toward the development of their scientific creativity outcomes.

RESULTS AND DISCUSSIONS

This data description table provides an overview of the pretest and posttest profiles of the objects studied in both sample groups. Data collection was carried out to identify the initial condition of the subjects before being given treatment, as well as to see the extent of changes that occurred after the intervention process was completed. Through the presentation of descriptive data that includes these minimum, maximum, and mean values, the differences in performance between the experimental group that applied a particular learning approach and the control group that used the conventional approach could be objectively analyzed before moving on to more in-depth inferential statistical testing.

Table 1. Pretest and Posttest Results of the Experimental and Control Group

Groups	N	Pre-Post	Min	Max	Mean
Experiment	25	Pretest	57	92	76
Experiments	25	Post test	70	100	89
Controls	25	Pretest	50	85	70
Controls	25	Post Test	70	100	87

Based on the data presented in the table above, there was an increase in the average score in both groups after the intervention was given. The experimental group recorded an average pretest score of 76, with a low score of 57 and a high of 92. After receiving the treatment, the average score of the experimental group increased to 89, with a range of values moving from a minimum of 70 to a perfect maximum score of 100. On the other hand, the control group started with a lower average pretest score of 70 (minimum 50 and maximum 85). After the implementation of conventional learning, the control group also showed an increase with the average posttest score reaching 87, where the lowest score was at 70 and the highest score managed to touch 100. Although both groups both achieved a maximum score of 100 on the final test, the experimental group showed descriptively higher final average achievement and starting point compared to the control group.

The next test focused on analyzing the difference in mean N-Gain data between the experimental group and the control group using an independent sample t-test at a significance level = 0.05. The results of this inferential statistical test serve as an empirical basis for accepting or rejecting the proposed work hypothesis, as well as proving the effectiveness of the application of the Science, Technology, Engineering, and Mathematics (STEM) approach to students' learning interests and creativity.

Table 1. Hypothesis Test Results

Variable	T Count	df	Sig value	Conclusion
Interest in Learning	3,06	48	0,025	Accepted Hypothesis
Student Creativity	4,454	48	0,025	Accepted Hypothesis

Based on the results of the analysis presented in the table above, a t-calculated value for the learning interest variable was 3.06 with a significance value (2-tailed) of 0.003, which is far below the significance threshold of 0.05. This shows that there is a significant difference in increased interest in learning between students who are taught with a STEM approach compared to the conventional model. Meanwhile, for the variable of student creativity, the t-count value was recorded at 4.454 with a significance value of 0.000 ($p < 0.05$), which means that the working hypothesis was also accepted conclusively. These statistical findings prove empirically that the application of STEM-based learning approaches has a significant positive influence and is more effective in boosting learning interest and triggering student creativity compared to conventional learning approaches.

To fully resolve the empirical gap highlighted in the methodology, the simple linear regression analysis revealed a robust model confirming the exact socio-cognitive relationship between the two endogenous variables. The calculation extracted a strong positive correlation coefficient ($r = 0.694$), indicating that as student interest in the interdisciplinary mechanics grew, their creative execution expanded proportionally. Crucially, the model isolated a coefficient of determination ($R^2 = 0.733$), proving that student learning interest explicitly accounted for a 73.3% variance contribution to scientific creativity outcomes, while the remaining 26.7% was influenced by external pedagogical or environmental factors.

This substantial 73.3% contribution is directly reflected in the granular breakdown of the four creativity rubrics observed during the mini waterwheel project. In terms of fluency, the experimental group generated a higher volume of alternative structural layouts compared to the rigid, singular designs of the control group. For flexibility, STEM-treated students demonstrated rapid shifts between utilizing physical structural supports (Engineering) and adjustments to water-flow volume (Science). The originality rubric was highly pronounced in the unique integration of low-cost, repurposed household plastics to construct durable wheel paddles. Finally, elaboration was manifested through the meticulous calculation and micro-adjustments students performed to achieve optimal rotation efficiency

The findings of this study show that the application of the Science, Technology, Engineering, and Mathematics (STEM) learning approach has a significant influence on the increase in learning interest of elementary school students. Active learning processes that integrate various disciplines have been proven to spark students' curiosity as well as increase their active participation in the classroom. These findings are in line with research conducted by Powers et al (2024) which found that the integration of STEAM learning (with the addition of the Arts component) significantly increases students' interest in learning and critical thinking skills at the elementary school level. When learning is connected to real-life activities and problem-solving that are close to students' daily lives, their emotional attachment and academic interest in the learning material will grow naturally (A. Antao & S. Morales, 2025).

Although the results of this study show a high increase in interest in learning, some previous studies have shown different results or provided critical notes regarding the consistency of the impact. Research by Costa & Reis (2025) shows that learning approaches that focus too much on evaluating technical performance or providing overly complex project instructions in the absence of an adaptive feedback system actually risk lowering students' intrinsic motivation because they feel burdened by technical demands. If the integration of engineering or technology aspects in STEM is not carefully designed according to the cognitive readiness of elementary school-age children, learning risks turning into just rigid procedural instruction, which ultimately lowers students' activity and interest in learning(Hewitt & Forcino, 2025).

In addition to learning interests, this study also proves that the STEM approach has a very strong positive contribution in triggering and increasing the creativity of elementary school students. Through project design, students are required to think flexibly, find alternative solutions, and give birth to new and original ideas. In line with that, Alim (2025)also emphasized that Project Based

Learning is very effective in developing the main aspects of student creativity, such as fluency, flexibility, and originality.

The statistical convergence of a high t-value (4.454) for creativity and a 73.3% variance contribution from learning interest carries profound educational significance for primary science pedagogy. This high percentage demonstrates that in the context of elementary-grade engineering, creative problem-solving is not an isolated cognitive trait; rather, it is heavily dependent on affective engagement and targeted interest. From an educational standpoint, these findings suggest that attempting to cultivate critical design skills or scientific inquiry in a vacuum—without first stimulating intrinsic interest through tangible, physical projects—is pedagogically inefficient. The mini waterwheel project serves as a socio-cognitive catalyst, proving that when abstract concepts like energy transformation are translated into physical, manipulative engineering tasks, the affective domain directly fuels the cognitive domain, unlocking high-order creative thinking skills in young learners

These results offer a more nuanced resolution to ongoing debates in STEM literature. The marked increase in the experimental group's creativity directly aligns with the foundational work of (Alim, 2025)Alim (2025), who asserted that project-based frameworks enhance structural flexibility and originality in children. However, this study's findings present a strong, systematic contrast to the critical arguments raised by Costa & Reis (2025) and Hewitt & Forcino (2025). Their previous works warned that integrating rigid technical performance standards or overly complex engineering tasks into early childhood classrooms tends to overburden the cognitive load of students, which subsequently suppresses both their intrinsic motivation and operational interest.The current research successfully resolves this contradiction. By socio cognitively tailoring the engineering phase to utilize low-cost, familiar, and highly malleable household plastics rather than high-precision prefabricated kits, the technical burden was minimized. This deliberate instructional design prevented cognitive overload, ensuring that technical demands acted as a prompt for creative exploration rather than a rigid procedural barrier.

The observed outcomes find strong justification in, and provide empirical validation for, established socio-constructivist learning theories, most notably Vygotsky's Zone of Proximal Development (ZPD) (Lambright, 2024) and Bandura's Self-Efficacy theory (Vaughan-Johnston & Jacobson, 2020). The phenomenon of elevated creativity and interest occurred because the physical mini waterwheel project functioned as a tangible, manipulative scaffold. By allowing students to actively adjust water flow volume (Science) and micro optimize wheel paddle structural design (Engineering) in a collaborative setting, the instructional model successfully translated abstract energy laws into concrete, visible variables. This immediate physical feedback loop validated the students' hypotheses in real-time, thereby strengthening their situational interest and creative self-efficacy.

Furthermore, these findings strongly support Amabile's Componential Theory of Creativity, which posits that intrinsic motivation is the single most critical component for unlocking creative performance(Chae et al., 2023). By establishing an empirical 73.3% contribution link, this study conclusively affirms Amabile's theoretical stance within the landscape of elementary STEM education, demonstrating that high emotional investment and contextual relevance are absolute prerequisites for original problem-solving execution

However, increasing creativity through STEM does not always occur automatically and uniformly in every learning condition (Alves-Oliveira et al., 2021; Saboorizadeh et al., 2023; Sirajudin et al., 2021; Tubb et al., 2020) Previous research from several experts warns that if the classroom innovation climate is not well formed, or if teachers dominate the project process too much, then the originality of students' ideas will not develop optimally (Fredagsvik, 2023). Research by Yu et al. (2018) indicates that in the absence of pure individual motivation and free space for exploration, students tend to simply imitate the teacher's instructions or examples of existing projects rather than creatively solve problems(Morphew et al., 2020; Norqvist et al., 2019; Southam & Costley, 2024). This challenge shows that STEM's success in sparking creativity relies heavily on the leeway of exploration provided, rather than simply a uniform completion of the final product (Patel et al., 2025).

The implications of these findings for schools and the world of education are the need to reconstruct learning methodologies at the elementary school level by abandoning conventional teaching patterns that focus on memorizing theories. Schools are recommended to begin to systematically facilitate and integrate STEM-based curriculum into their educational unit's operational curriculum documents. This requires training to increase the capacity of teachers in designing learning media based on problem solving and interdisciplinary projects. Thus, schools not only function as a place for theoretical knowledge transfer, but also transform into an innovative ecosystem that is able to prepare the younger generation who have critical, creative, and adaptive thinking skills from an early age

CONCLUSION

This study successfully demonstrates optimal compatibility between the baseline pedagogical challenges identified in the introduction and the empirical outcomes derived from the implementation of an integrated STEM approach assisted by a mini waterwheel project. By transitioning abstract energy transformation concepts into a tangible, interdisciplinary engineering framework, this intervention significantly outpaces conventional models in stimulating student interest and fostering scientific creativity within elementary science education this research reinforces social constructivist learning frameworks and validates Amabile's Componential Theory of Creativity by establishing a robust empirical link that identifies intrinsic learning interest as a foundational prerequisite for operational creativity in early childhood engineering education. Practically, this study provides a concrete, low-cost instructional blueprint for basic education institutions to reconstruct rigid, paper-based science curricula into dynamic, interdisciplinary problem-solving ecosystems that nurture critical and adaptive thinking skills from an early age. However, several critical limitations must be explicitly acknowledged. First, the evaluation of student creativity was confined to a short-term intervention window, which limits the ability to confirm the permanent retention of these creative reasoning skills. Second, the sample size was restricted to fifty students within a single homogenous urban school zone, meaning the results should be interpreted with caution as they may not fully represent rural demographics or regions with severe institutional resource constraints. These factors suggest that the absolute generalization of the pedagogical efficacy reported here remains bounded by specific institutional readiness and immediate classroom innovation climates. To extend and validate these findings, future research should move toward longitudinal designs that track the long-term memory retention of abstract science concepts across subsequent academic years. Specifically, promising research directions include integrating these physical manipulative waterwheel models with interactive digital twins or virtual laboratory software to assess the intersection of tactile and virtual engineering reasoning. Furthermore, future investigations should employ larger-scale, multi-site randomized controlled trials across diverse socio-economic school districts to systematically isolate how varying levels of teacher interdisciplinary readiness and institutional scaffolding impact the scalability of this STEM framework.

References

A. Antao, M., & S. Morales, J. R. (2025). Increasing the interest of students in problem-solving through authentic learning experiences: Lens from non-math enthusiast learners. *Environment and Social Psychology*, *10*(2). https://doi.org/10.59429/esp.v10i2.3175

Alim, T. K. (2025). The Role of Project-Based Learning in Enhancing Elementary School Students' Creativity: A Literature Review. *Al-Hasib: Manajemen Pendidikan Islam*, *2*(1), 186–203.

Alves-Oliveira, P., Arriaga, P., Nogueira, S. I., & Paiva, A. (2021). Robotics-Based Interventions for Children's Creativity. *Creativity and Cognition*, 1–8. https://doi.org/10.1145/3450741.3465267
Azis, K. R., Handayani, R. D., & Lesmono, A. D. (2023). The Implementation of STEM-Integrated Project-Based Learning Model on Renewable Energy Topic Through a Windmill Simulation. *Journal of Physics: Conference Series*, *2623*(1). https://doi.org/10.1088/1742-6596/2623/1/012017
Chae, H.-C., Koh, C. E., & Nguyen, Q. (2023). Individual Creativity and Acceptance of Emerging Information Technology. *Journal of Computer Information Systems*, *63*(6), 1460–1476. https://doi.org/10.1080/08874417.2023.2169847
Costa, L. M. G., & Reis, M. J. C. S. (2025). Motivational Teaching Techniques in Secondary and Higher Education: A Systematic Review of Active Learning Methodologies. *Digital*, *5*(3), 40. https://doi.org/10.3390/digital5030040
Dossymov, Y., Ramankulov, S., Genc, N., Çoruh, A., Nurizinova, M., & Zhaksylyk, N. (2026). Integrating renewable energy based on science, technology, engineering and mathematics projects in promoting. *Global Journal of Environmental Science and Management*, *12*(2). https://doi.org/10.22034/gjesm.2026.02.06
Fredagsvik, M. S. (2023). The challenge of supporting creativity in problem-solving projects in science: a study of teachers' conversational practices with students. *Research in Science & Technological Education*, *41*(1), 289–305. https://doi.org/10.1080/02635143.2021.1898359
Hewitt, T., & Forcino, F. (2025). The influence of a STEM unit on the interest in and understanding of science and engineering between elementary school girls and boys. *Discover Education*, *4*(1), 20. https://doi.org/10.1007/s44217-025-00404-x
Jannah, M., Oviana, W., Hayati, Z., Hidayat, R., Usman, J., & Noris, M. (2025). Enhancing Pre-Service Teachers' Science Process Skills Through Open-Ended and Guided Inquiry-Based Learning. *Jurnal Ilmiah Peuradeun*, *13*(2), 1235–1262. https://doi.org/10.26811/peuradeun.v13i2.1174
Lambright, K. (2024). The Effect of a Teacher's Mindset on the Cascading Zones of Proximal Development: A Systematic Review. *Technology, Knowledge and Learning*, *29*(3), 1313–1329. https://doi.org/10.1007/s10758-023-09696-0
Morphew, J. W., Gladding, G. E., & Mestre, J. P. (2020). Effect of presentation style and problem-solving attempts on metacognition and learning from solution videos. *Physical Review Physics Education Research*, *16*(1), 010104. https://doi.org/10.1103/PhysRevPhysEducRes.16.010104
Murcia, K. (2008). Teaching Science Creatively: Engaging Primary Teacher Education Students with Interactive Whiteboard Technology. *The International Journal of Interdisciplinary Social Sciences: Annual Review*, *3*(3), 45–52. https://doi.org/10.18848/1833-1882/CGP/v03i03/59353
Norqvist, M., Jonsson, B., Lithner, J., Qwillbard, T., & Holm, L. (2019). Investigating algorithmic and creative reasoning strategies by eye tracking. *The Journal of Mathematical Behavior*, *55*, 100701. https://doi.org/10.1016/j.jmathb.2019.03.008
Patel, J., Rutledge, A., Cellitioci, J., Giordano, A., & Moore, R. (2025). Investigating Perceptions of Inventiveness and Entrepreneurial Mindsets in Late Elementary School Students. *2025 ASEE Annual Conference & Exposition Proceedings*. https://doi.org/10.18260/1-2--56890
Powers, J., Brown, S., Bogle, R., Musgrove, A., & Wemette, S. (2024). Exploring the Impact of Integrated STEAM Lessons on Third-Graders' Knowledge, Identity, and Attitudes. *Journal of Interactive Learning Research*, *35*(3), 309–351. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85209772732&partnerID=40&md5=884c18c586658ce55ccf9f8e1f6b2f6f
Putra, P., & Kumano, Y. (2018). Energy Learning Progression and STEM Conceptualization Among Pre-service Science Teachers in Japan and Indonesia. *The New Educational Review*, *53*(3), 153–162. https://doi.org/10.15804/tner.2018.53.3.13
Rahardjanto, A., & Susilowati, R. (2018). Study of Learning Strategy Integration of Science and Religion on the Development of Student Character. *Proceedings of the 5th International Conference on Community Development (AMCA 2018)*. https://doi.org/10.2991/amca-18.2018.178
Ramaila, S. (2026). Transformative pedag'og'y: Harnessing' constructivist and participatory approaches to foster learner eng'age'ment and effective instruction. *Perspectives in Education*, *44*(1), 180–194. https://doi.org/10.38140/PIE.V44I1.8559
Saboorizadeh, J., He, H., Burgoyne, S., Pfeiffer, F., Hunt, H., & Strobel, J. (2023). *Theatre-Based Creativity Activities for the Development of Entrepreneurial Mindsets in Engineering* (pp. 383–402). https://doi.org/10.1007/978-3-031-17816-0_16
Said-Metwaly, S., Van den Noortgate, W., & Barbot, B. (2021). Torrance test of creative thinking-verbal, Arabic version: Measurement invariance and latent mean differences across gender, year of study, and academic

major. *Thinking Skills and Creativity*, *39*, 100768. https://doi.org/10.1016/j.tsc.2020.100768
Sirajudin, N., Suratno, J., & Pamuti. (2021). Developing creativity through STEM education. *Journal of Physics: Conference Series*, *1806*(1), 012211. https://doi.org/10.1088/1742-6596/1806/1/012211
Southam, A., & Costley, J. (2024). The role of modelling during instruction in collaborative creativity. *Thinking Skills and Creativity*, *54*, 101660. https://doi.org/10.1016/j.tsc.2024.101660
Sriyansyah, S. P., & Azhari, D. (2017). Addressing an undergraduate research issue about normalized change for critical thinking test. *Jurnal Pendidikan IPA Indonesia*, *6*(1), 138–144. https://doi.org/10.15294/jpii.v6i1.9602
Syamra, F. M., & Suryadi, A. (2025). Comparing project-based learning and integrated STEM approach in enhancing scientific creativity in renewable energy education. *Pedagogical Research*, *10*(3), em0244. https://doi.org/10.29333/pr/16751
Tubb, A. L., Cropley, D. H., Marrone, R. L., Patston, T., & Kaufman, J. C. (2020). The development of mathematical creativity across high school: Increasing, decreasing, or both? *Thinking Skills and Creativity*, *35*, 100634. https://doi.org/10.1016/j.tsc.2020.100634
Vaughan-Johnston, T. I., & Jacobson, J. A. (2020). Self-efficacy theory. In *The Wiley Encyclopedia of Personality and Individual Differences, Models and Theories* (pp. 375–379). wiley. https://doi.org/10.1002/9781119547143.ch62
Vivian Wong Shao Yun, Norhidayah Md Ulang, & Siti Hamidah Husain. (2023). Measuring the Internal Consistency and Reliability of the Hierarchy of Controls in Preventing Infectious Diseases on Construction Sites: The Kuder-Richardson (KR-20) and Cronbach's Alpha. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *33*(1), 392–405. https://doi.org/10.37934/araset.33.1.392405
Widiyatmoko, A., & Shimizu, K. (2018). An overview of conceptual understanding in science education curriculum in Indonesia. *Journal of Physics: Conference Series*, *983*(1). https://doi.org/10.1088/1742-6596/983/1/012044
Zaini, M., Purwowidodo, A., & Nuryanti. (2023). Hybrid-Generative Learning: Learning Outcomes, Creative Thinking Skills, Learning Interest in Islamic Religious Education Subjects in Junior High School. *Jurnal Pendidikan Agama Islam*, *20*(2), 262–278. https://doi.org/10.14421/jpai.v20i2.7846