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Exploring Students' Perceptions and the Need for STEM-Based Games Box Learning Media on Environmental Pollution to Support Creative Thinking in High School Physics

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Abstract: This study explores students' perceptions of creative thinking and examines the need to develop a STEM-based "Games Box" learning media for environmental pollution topics in high school physics. A descriptive quantitative approach was used, involving 277 students who completed a Likert-scale questionnaire covering six aspects, including creative thinking perception, learning media needs, STEM-based learning needs, interactive learning preferences, physical media accessibility, and readiness to use the Games Box. The findings show that students generally perceive their creative thinking abilities at a moderate level, particularly in fluency (mean = 2.87; 57.4%) and originality (mean = 2.74; 54.8%). At the same time, students express a clear need for more engaging and interactive learning media that integrate STEM approaches to help them understand abstract physics concepts more effectively. Responses also indicate a strong preference for learning media that are hands-on, game-based, and capable of making learning more meaningful and enjoyable. Overall, the results suggest that developing a STEM-based Games Box is both relevant and necessary to support creative thinking in learning environmental pollution. This study also emphasizes the importance of connecting environmental issues with physics concepts such as acoustics in noise pollution, thermodynamics in thermal pollution, and radiation in radioactive contamination. In general, the findings provide a solid foundation for designing innovative, student-centered learning media that align with the demands of 21st-century education.

Keywords: Creative Thinking; Environmental Pollution; Games Box; Learning Media; STEM

Introduction

Physics education at the senior high school level emphasizes not only the mastery of theoretical concepts but also the development of 21st-century skills, including creativity, critical thinking, collaboration, and communication (Azmi et al., 2024). The current curriculum mandates a student-centered and contextualized learning process that bridges scientific concepts with real-world issues encountered in daily life (Jamil & Hasanuddin, 2026). Khafidh et al. (2025) explained that this competencies are integral to modern curricula, aiming to prepare students to navigate the challenges of a complex, dynamic, and technology driven world. However, the implementation of physics instruction in the classroom remains dominated by conventional methods and a lack of variety in learning media, leading to a decline in students' active engagement and a deficiency in their creative thinking skills.

However, the implementation of physics learning in schools still faces several challenges. In many cases, the learning process is still dominated by conventional, teacher-centered methods that are largely theoretical and do not actively involve students (Zhang et al., 2021). In addition, the limited variety of instructional media

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makes it more difficult for students to understand abstract concepts, including environmental pollution topics (Gustini et al., 2023). According to Garg & Dhiman (2022), this condition is considered less effective in supporting students' conceptual understanding and creative thinking skills. Monotonous learning environments may also reduce students' motivation and engagement in the learning process (Widiana, 2022).

Kurniarta et al. (2025)said that one approach that has strong potential to address these challenges is Game-Based Learning (GBL). This approach uses game elements to create learning experiences that are more interactive, engaging, and enjoyable for students. Previous research by Hartt et al. (2020) revealed that game-based learning can support student engagement and conceptual understanding. GBL has been proven to increase learning motivation while encouraging students to think more flexibly and creatively in solving educational problems (Fernando et al., 2024). In addition, the integration of the STEM (Science, Technology, Engineering, and Mathematics) approach is also considered effective in supporting the development of creative thinking and problem-solving skills by applying scientific concepts to real-world situations competencies (Azizah & Angelina, 2020). Previous studies have reported that STEM-based learning can support active and contextual learning processes (Wang et al., 2022), facilitate project-based learning experiences (Reiss & Filtzinger, 2023), and foster students' creativity and critical thinking skills (Nugraha et al., 2024). In addition, STEM-based learning is considered flexible for implementation in various educational contexts (Priyani & Nawawi, 2021). The STEM-based learning can support students in developing creative and critical thinking skills across different educational levels. It also provides opportunities for students to explore ideas, carry out investigations, and work together to develop solutions to real world problems in a more meaningful and engaging way.

Despite this, most current developments in game-based learning tend to focus primarily on digital media (Yulianci et al., 2021). In fact, physical learning media that can be directly touched and manipulated still play an important role, especially for high school students in understanding abstract concepts. Physical media can provide more concrete and interactive learning experiences, allowing students to engage more actively in the learning process. Although many studies have discussed STEM and game-based learning, the integration of STEM-based physical game media in physics education, particularly for environmental pollution topics, remains relatively limited (Chercules & Sriyanti, 2023). In addition, studies exploring students' perceptions of creative thinking and the need for developing STEM-based Games Box media in the context of high school physics learning are still scarce. Therefore, the development of a STEM-based Games Box offers a promising and innovative alternative for creating more contextual, interactive, and student-centered physics learning experiences.

Before developing learning media, it is important to conduct a needs analysis and explore students' perceptions to ensure that the proposed media aligns with their characteristics and learning needs. This analysis helps identify students' perceptions of creative thinking, their need for interactive learning media, their interest in STEM approaches, and their readiness to use physical game-based learning media. The findings from this needs analysis can provide an empirical foundation for designing learning media that are more relevant, engaging, and appropriate for classroom learning conditions.

Based on these considerations, this study was conducted to explore students' perceptions of creative thinking and identify the need for developing a STEM-based Games Box for environmental pollution topics in high school physics learning. The findings of this study are expected to provide an empirical basis for developing innovative and contextual learning media that align with the demands of 21st-century education. The novelty of this study lies in exploring students' perceptions of creative thinking and the need for STEM-based physical game media on environmental pollution topics within the context of high school physics learning, an area that has received limited attention in previous studies.

Method

This study employed a descriptive quantitative approach aimed at examining students' perceptions of creative thinking abilities and identifying the need for developing a STEM-based Games Box learning medium on environmental pollution topics in senior high school physics learning.

The population of this study consisted of students from SMA Negeri 22 Palembang who had previously studied environmental pollution in physics classes. The sample was selected using a random sampling technique, involving 277 students who met the criteria of having learned the topic and were willing to participate in completing the research instruments.

The research instrument was a closed-ended questionnaire using a 5-point Likert scale, ranging from strongly disagree to strongly agree. The questionnaire covered six key aspects: (1) students' initial perceptions of creative thinking skills, (2) needs for learning media, (3) needs for STEM-based learning media, (4) preference

for interactive learning, (5) accessibility of physical media, and (6) readiness to use the Games Box as a learning medium.

Prior to data collection, the instrument was validated for content validity by two physics education experts and two physics teachers. The results showed a Content Validity Ratio (CVR) of 1 for all items, indicating that every item was considered relevant and appropriate for use. The instrument was then tested for reliability to determine internal consistency among items. The analysis yielded a Cronbach's Alpha value of 0.83, indicating high reliability; therefore, the instrument was considered consistent and suitable for data collection.

Data were collected using Google Forms, which were distributed with the assistance of subject teachers and school communication channels. This method was chosen due to its efficiency in reaching a large number of respondents and facilitating the data collection process. The collected data were analyzed using descriptive statistics, specifically by calculating percentages and mean scores for each indicator. The results were then interpreted using Likert scale criteria to describe students' levels of perception and their perceived needs for the learning media under investigation.

Result and Discussion

Results

A total of 277 students from SMA Negeri 22 Palembang participated in this study. Data were collected through an online questionnaire distributed via Google Forms. The students are categorized by gender as presented in Table 1.

Table 1. Gender distribution of respondents

Gender	Frequency	Percentage (%)
Male	105	37.9
Female	172	62.1
Total	277	100

This study aims to analyze the necessity for innovative learning media in the form of a STEM-based 'Games Box' for environmental pollution topics. The research instrument encompasses five primary aspects: (1) students' initial perceptions of creative thinking, (2) the necessity for learning media, (3) the demand for STEM-based media, (4) the availability of physical media, and (5) readiness to utilize the Games Box. Each item is measured using a 5-point Likert scale. The first aspect focuses on students' initial perceptions of creative thinking, consisting of three statements designed to illustrate students' insights or perspectives regarding creative thinking.

Table 2. Initial creative thinking perceptions of students

Statement	SA %	A %	N %	D %	SD %
I frequently generate original ideas that differ from those of my peers.	40.8	37.9	14.8	3.6	2.9
I am capable of integrating these original ideas to determine solutions to problems.	318	45.5	15.5	7.2	0
I am not deterred by the possibility of making mistakes when exploring new concepts.	43.7	33.2	13.4	6.9	2.9

Note: Strongly Disagree (SD); Disagree (D); Neutral (N); Agree (A); Strongly Agree (SA)

Based on Table 2 regarding students' initial perceptions of creative thinking, it can be observed that students demonstrate a positive self-perception of creative thinking abilities. In the first statement, a large proportion of students agreed (37.9%) and strongly agreed (40.8%) that they frequently generate original ideas different from their peers, indicating a perceived tendency toward originality. In the second statement, most students also agreed (45.5%) and strongly agreed (31.8%) that they are able to integrate new ideas to solve problems, reflecting perceived cognitive flexibility and elaboration skills. Meanwhile, in the third statement, although a small proportion of students expressed concern about making mistakes when exploring new ideas, the majority still agreed (33.2%) and strongly agreed (43.7%) that they are willing to engage in new and unfamiliar thinking processes. Overall, these responses reflect students' positive self-assessment of creative thinking, rather than measured creative performance.

Table 3. Student requirements for instructional media

Statement	SA %	A %	N %	D %	SD %
I find environmental pollution material difficult to comprehend when it is explained solely by the teacher without the support of instructional media.	18.1	36.8	22	16.6	6.5
The utilization of instructional media renders environmental pollution topics more engaging and prevents them from being monotonous.	52.3	33.9	7.9	3.6	2.2
I require instructional media that can assist me in visualizing environmental pollution concepts.	43.7	39.7	11.9	2.9	1.8

Statement	SA %	A %	N %	D %	SD %
I prefer studying environmental pollution through the use of interactive media.	40.8	36.8	18.4	2.5	1.4

Note: Strongly Disagree (SD); Disagree (D); Neutral (N); Agree (A); Strongly Agree (SA)

Based on Table 3 regarding students' needs for instructional media, the findings indicate a strong perceived need for supportive learning media in understanding environmental pollution topics. A considerable number of students agreed (36.8%) and strongly agreed (18.1%) that they find the material difficult to understand when it is explained only through teacher-centered instruction, suggesting the importance of additional learning support. Furthermore, most students agreed (52.3%) and strongly agreed (33.9%) that learning media make the topic more engaging and less monotonous. Students also expressed a clear need for visualization support, as shown by the high agreement for statements related to conceptual visualization and interactive learning preferences. Overall, these results highlight the importance of instructional media in improving learning accessibility and engagement.

Table 4. Student requirements for STEM based media

Statement	SA %	A %	N %	D %	SD %
I am interested in lessons that integrate Science and Technology and Engineering and Mathematics (STEM).	27.8	37.5	16.2	14.8	3.6
I believe that environmental pollution material will be easier to comprehend if it is linked to Science and Technology and Engineering and Mathematics concepts (STEM).	19.5	37.5	22	15.9	5.1
I wish to understand how science and technology are utilized to resolve environmental pollution problems.	45.1	39	10.5	4.3	1.1
Learning media based on Science and Technology and Engineering and Mathematics will encourage me to think broadly and creatively.	36.5	37.5	17.3	5.4	3.2

Note: Strongly Disagree (SD); Disagree (D); Neutral (N); Agree (A); Strongly Agree (SA)

Based on Table 4 regarding students' needs for STEM-based learning media, the results show that students generally have a positive attitude toward STEM-integrated learning. Most students agreed (37.5%) and strongly agreed (27.8%) that they are interested in learning that integrates Science, Technology, Engineering, and Mathematics. In addition, students believe that linking environmental pollution topics with STEM concepts can improve their understanding, as reflected in the agreement levels for the relevant statements. Students also expressed interest in understanding how science and technology are applied to solve environmental problems. Overall, these responses indicate that STEM-based learning is perceived as relevant and beneficial for supporting conceptual understanding and learning engagement.

Table 5. Physical Media Accessibility

Statement	SA %	A %	N %	D %	SD %
I prefer utilizing physical instructional media that can be handled and manipulated.	56	31	10.1	2.5	0.4
The compact size and form of the Games Box will allow for greater portability and ease of use.	40.8	39.4	15.2	3.6	1.1

Note: Strongly Disagree (SD); Disagree (D); Neutral (N); Agree (A); Strongly Agree (SA)

Based on Table 5 regarding the accessibility of physical learning media, students show a strong preference for hands-on instructional media that can be directly manipulated. The majority of students agreed (31%) and strongly agreed (56%) that they prefer learning media that are tangible and interactive. In addition, students agreed that the compact form of the Games Box supports portability and ease of use in learning activities. These findings suggest that physical media are perceived as more engaging and practical for supporting active learning experiences.

Based on Table 6, students show a strong readiness and positive attitude toward using the Games Box as a learning medium. Most students are confident that the Games Box is durable and appropriate for classroom use, indicating that they see it as a practical and reliable learning tool.

In addition, many students are willing to take part in preparing the media before learning begins. This reflects a sense of independence and active involvement, showing that they are not only users of the media but also willing participants in the learning process.

Students also feel that the instructions for using the Games Box are clear and easy to follow. Their high level of interest in using this media for learning environmental pollution, along with the belief that it can make learning more enjoyable, further highlights its potential acceptance in the classroom. Overall, these responses suggest that students are well-prepared and open to the use of a physical, game-based STEM learning media in physics learning.

Table 6. Student readiness for utilizing the Games Box

Statement	SA %	A %	N %	D %	SD %
I am confident that the Games Box media will be durable and resistant to damage.	21.3	46.2	23.1	7.9	1.4
I am willing to assemble or prepare the Games Box media prior to its utilization.	31.8	39	18.4	9	1.8
The instructions for utilizing the Games Box media must be easy to comprehend and uncomplicated.	58.5	22.7	13.7	3.6	1.4
I am interested in utilizing the Games Box instructional media for environmental pollution topics.	48.7	35.4	12.3	2.2	1.4
I am confident that the Games Box will enhance the enjoyment of environmental pollution learning.	55.6	33.2	9.7	0.4	1.1

Note: Strongly Disagree (SD); Disagree (D); Neutral (N); Agree (A); Strongly Agree (SA)

Discussion

This study explores students' perceptions of creative thinking abilities and their learning needs in relation to the development of STEM-based Games Box media for environmental pollution topics in physics learning. The discussion is organized around six key aspects, including creative thinking perception, learning media needs, STEM-based learning orientation, physical learning media accessibility, and student readiness. Overall, the findings provide a clear overview of students' learning experiences and indicate several instructional aspects that still require improvement and innovation.

Students generally hold a positive view of their creative thinking abilities, particularly in generating original ideas and proposing alternative solutions in problem-solving situations (Fatmawati et al., 2022). This suggests that students perceive themselves as capable of engaging in divergent thinking. However, some students still experience hesitation when dealing with open-ended tasks that require exploration and risk-taking, indicating that such learning situations are not yet fully familiar in classroom practice. Rather than reflecting actual ability, these responses describe students' perceived creative capacity within current learning conditions. This condition indicates a creative thinking gap, where perceived abilities have not fully translated into consistent performance in open and ill-structured learning contexts.

This finding is consistent with previous studies showing that students' creative thinking skills are generally at a moderate level, with originality tending to be stronger than flexibility (Melur et al., 2025; Nazhifah et al., 2023). This pattern suggests that students are more accustomed to structured tasks and may face difficulties when dealing with problems that require multiple solution pathways (Tan & Kocsis, 2024; Wu & Molnár, 2022). Therefore, learning environments need to provide greater opportunities for exploration, inquiry, and problem-solving activities. This also reflects a persistent gap between current instructional practices and learning environments that fully support the development of creative thinking skills (Zhong et al., 2025).

In terms of learning media needs, students often struggle to understand environmental pollution concepts when learning is delivered through conventional, teacher-centered instruction. This indicates that their learning experience is still largely characterized by passive knowledge reception rather than active knowledge construction. This condition indicates a gap in learning media, particularly in supporting more meaningful and engaging learning experiences.

This is supported by previous studies showing that traditional science instruction tends to limit student participation and conceptual understanding, highlighting the need for more visual and supportive learning environments (Ichsan et al., 2019). Environmental pollution is also a complex topic that requires visual and multimedia representations to support conceptual understanding (Dewi et al., 2022; Hanafi et al., 2021). In addition, learning environments with limited interaction can reduce students' ability to connect classroom concepts with real-life phenomena (Perea et al., 2025; Suryaningsih & Nurlita, 2021). Overall, this reveals a mismatch between abstract content delivery and students' need for contextual and meaningful learning experiences.

Building on this gap, STEM-based learning emerges as a relevant approach to connect abstract physics concepts with real-world contexts. By integrating science, technology, engineering, and mathematics,

STEM enables students to engage in authentic problem-solving rather than rote memorization. This also highlights a STEM integration gap, where students still require more structured opportunities to experience interdisciplinary learning in meaningful contexts.

Research has shown that STEM learning enhances student engagement and conceptual understanding through inquiry and exploration-based activities (Pertiwi et al., 2024). It also supports the development of higher-order thinking skills by involving students in analyzing problems, designing solutions, and evaluating real environmental issues such as pollution (Ramadhona et al., 2026). Furthermore, STEM contributes to the development of 21st-century skills such as communication, collaboration, and critical thinking (Rahman et al., 2023), as well as applied problem-solving abilities in contextual settings (Vasconcelos & Dos Santos, 2023). STEM education also strengthens integrated disciplinary understanding through structured learning processes, especially when combined with discovery-based and collaborative approaches that enhance engagement (Nugraha et al., 2024). Overall, STEM serves as a bridge between abstract concepts and real-world phenomena, making learning more meaningful and relevant to contemporary educational demands (Vennix et al., 2017).

Regarding physical learning media accessibility, students tend to prefer learning tools that allow direct manipulation and hands-on interaction. This indicates that tactile experience still plays an important role in understanding abstract physics concepts, particularly when supported by concrete visual representations. This condition reflects a physical media gap, where students' preference for hands-on learning is not yet fully supported by available classroom resources.

Previous studies confirm that hands-on learning improves conceptual understanding through direct interaction with learning materials (Fior et al., 2025). Similarly, manipulative-based activities help students apply scientific concepts more effectively compared to passive instructional approaches (Shao et al., 2024). Although students generally have adequate access to digital devices, their exposure to physical learning tools remains limited, creating a gap between digital familiarity and hands-on learning experience.

While digital technologies support access to information, physical learning media remain essential for developing sensory engagement and strengthening conceptual understanding (Partarakis et al., 2021). Therefore, a balanced integration of physical and digital resources is necessary. This can be achieved by combining tangible materials with digital support such as videos, simulations, or QR-based learning content. Such integration enables both experiential learning and cognitive reinforcement, resulting in more meaningful learning outcomes (Chang & Chang, 2023). However, physical learning media must be carefully designed to ensure that hands-on activities also promote deeper conceptual understanding rather than surface-level engagement (Papalazarou et al., 2024). This highlights the need for more integrated and pedagogically well-designed learning media systems.

Finally, students demonstrate a high level of readiness to use the Games Box as a physical, game-based learning medium. This readiness is reflected not only in their confidence regarding its practicality, but also in their willingness to participate in structured and collaborative learning activities. Students show enthusiasm toward challenges, rules, and group-based tasks, indicating openness to more active and participatory learning environments.

This is consistent with studies showing that gamified learning can enhance student engagement and motivation through structured challenges and feedback mechanisms that make learning more meaningful (Ortiz-Rojas et al., 2025). In addition, game-based learning increases intrinsic motivation and active participation by involving students more directly in the learning process (Sharmin et al., 2024), while also strengthening collaboration skills in learning activities (Nurhayati & Fathurrohman, 2025). These findings are further supported by evidence that gamification can significantly improve both engagement and conceptual understanding (Cuabo et al., 2024; Nuradhisti & Prasetyanigtyas, 2025). From a broader perspective, this readiness reflects an important opportunity to address the interconnected learning gaps identified across creative thinking, instructional media, STEM integration, and physical learning experiences.

Overall, students' readiness to use the Games Box does not merely indicate acceptance of a new learning medium, but also highlights its potential to respond to multiple learning gaps identified in this study. This emphasizes the necessity of developing integrated STEM-based physical–digital learning media such as the Games Box, which can support more meaningful, engaging, and contextually relevant physics learning experiences while fostering 21st-century competencies.

Conclusion

Based on the overall needs analysis, it can be concluded that the development of a STEM-based Games Box for environmental pollution topics has strong potential for implementation. The findings show that students have a high interest in innovative learning media. Students also demonstrated positive responses toward STEM-based approaches, readiness to engage in

gamified learning, and accessibility that supports the application of a hybrid design. This hybrid design aims to bridge students' digital literacy with the need for direct sensorimotor experiences through physical learning media. The proposed media also has the potential to facilitate students' motivation, engagement, and creative thinking skills through discovery-based learning and contextual problem-solving activities. Practically, these findings may serve as a reference for teachers and media developers in designing more interactive and contextual learning experiences. Theoretically, this study strengthens the integration of STEM approaches, gamification, and environmental education in the learning process. To ensure its effectiveness, future studies are recommended to continue with prototype development and experimental testing involving broader participants. Further research may also focus on developing implementation guidelines to support teachers in applying this learning innovation effectively in classroom settings.

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The authors declare no conflict of interest.

References

Azizah, A., & Angelina, N. N. (2020). Efektivitas Pembelajaran Berbasis STEM dalam Meningkatkan Kreativitas dan Keterampilan Berpikir Kritis Siswa SMP Negeri 1 Jombang. *Journal of Science and Mathematics Education*, *1*(2), 32–38. https://doi.org/10.70716/josme.v1i2.169

Azmi, U., Safrijal, & Rahmi, M. (2024). Analysis of 4C skills (critical thinking, creativity and innovation, collaboration, and communication) of physics education students in facing the Industrial Revolution 4.0. *Jurnal Penelitian Pendidikan IPA*, *10*(2), 695–703. https://doi.org/10.29303/jppipa.v10i2.5584

Chang, C. W., & Chang, S. H. (2023). The Impact of Digital Disruption: Influences of Digital Media and Social Networks on Forming Digital Natives' Attitude. *SAGE Open*, *13*(3), 1–10. https://doi.org/10.1177/21582440231191741

Chercules, I., & Sriyanti, I. (2023). Development of Electronic Books Using Website 2 APK Builder Pro Based on Science, Technology, Engineering, and Mathematics (STEM) to Improve Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 9381–9390. https://doi.org/10.29303/jppipa.v9i11.5182

Cuabo, M. P., F., S. J., F., Baluyos, R., & G. (2024). Mystery Box Game: A Game-Based Learning to Improve the Academic Achievement of Grade 10 Learners in Probability. *International Journal of Innovative Science and Research Technology*, 2238–2247. https://doi.org/10.38124/ijisrt/ijisrt24sep532

Dewi, R., Sutarba, M. U., Unidah, U., Rahmi, S. U., & Hadiansyah, Y. (2022). Pemanfaatan media video interaktif dalam pengembangan lebih lanjut hasil belajar siswa pada materi pencemaran alam di sekolah menengah pertama. *Educatio*, *17*(1), 70–76. https://doi.org/10.29408/edc.v17i1.5725

Fatmawati, B., Jannah, B. M., & Sasmita, M. (2022). Students' Creative Thinking Ability Through Creative Problem Solving based Learning. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 2384–2388. https://doi.org/10.29303/jppipa.v8i4.1846

Fernando, Y., Eka Fitria, T., & Zaturrahmi, Z. (2024). Model pembelajaran game based learning dalam pembelajaran fisika. *Al-Khazini: Jurnal Pendidikan Fisika*, *4*(2), 70–76. https://doi.org/10.24252/al-khazini.v4i2.45066

Fior, G., Fonda, C., & Canessa, E. (2025). *Hands-on STEM Learning Experiences using Digital Technologies*. STEM Education. Retrieved from http://arxiv.org/abs/2408.00781

Garg, M., & Dhiman, M. (2022). Impact of environment education in shaping environmental knowledge, concern and behavior. *Research Gate Journal*, 1–25. Retrieved from https://shorturl.asia/mFVTH

Gustini, H., Ruhiat, Y., & Nulhakim, L. (2023). Development of Nearpod-Based Interactive Learning Media on Environmental Pollution Materials. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1314–1319. https://doi.org/10.29303/jppipa.v9i3.3061

Hanafi, Y., Ratna Ma'rifah, D., Abdillah Nurusman, A., & Alif Fahmi Rizki, G. (2021). Efektivitas Video

Learning Materi Pencemaran Lingkungan Pada Mata Kuliah Ilmu Lingkungan Prodi Pendidikan Biologi FKIP UAD. *BIODIK*, *7*(4), 127–135. https://doi.org/10.22437/bio.v7i4.14186

Hartt, M., Hosseini, H., & Mostafapour, M. (2020). Game on: Exploring the effectiveness of game-based learning. *Planning Practice & Research*, *35*(5), 589–604. https://doi.org/10.1080/02697459.2020.1778859

Ichsan, I. Z., Sigit, D. V, & Miarsyah, M. (2019). Environmental Learning based on Higher Order Thinking Skills: A Needs Assessment. *International Journal for Educational and Vocational Studies*, *1*(1), 21. https://doi.org/10.29103/ijevs.v1i1.1389

Jamil, & Hasanuddin. (2026). Adiwiyata: Integrating Environmental Education and PKLH-Based Sustainability into Teaching and Learning. *Jurnal Penelitian Pendidikan IPA*, *12*(1), 117–128. https://doi.org/10.29303/jppipa.v12i1.13875

Khafidh, A. N., Widyawati, F., Yani, S., & Nuraeni, Y. (2025). Pemanfaatan Game Based Learning dan Gamifikasi Adaptif dalam Pembelajaran STEM: Penelitian. *Jurnal Pengabdian Masyarakat Dan Riset Pendidikan*, *4*(2), 9468–9477. https://doi.org/10.31004/jerkin.v4i2.3419

Kurniarta, I. M. A., Redhana, I. W., & Tika, I. N. (2025). Game-Based Learning for Improving Students' Creative Thinking Skills in Science Learning: A Systematic Literature Review. *Jurnal Penelitian Pendidikan IPA*, *11*(12), 22–32. https://doi.org/10.29303/jppipa.v11i12.12014

Melur, E. C., Liliawati, W., Samsudin, A., Aviyanti, L., & Setiawan, A. (2025). Profile of Creative Thinking Skills and Analysis of Students' Perceptions of Physics Learning. *Jurnal Penelitian Pendidikan IPA*, *11*(5), 1029–1035. https://doi.org/10.29303/jppipa.v11i5.10260

Nazhifah, N., Wiyono, K., Ismet, & Azairok, M. (2023). Profile of Physics Creative Thinking Skills for High School Students in The 21st Century. *Jurnal Inovasi Pendidikan Fisika Dan Riset Ilmiah*, *7*(1), 1–11. https://doi.org/10.30599/jipfri.v7i1.2131

Nugraha, M. G., Kidman, G., & Tan, H. (2024). Interdisciplinary STEM education foundational concepts: Implementation for knowledge creation. *Eurasia Journal of Mathematics, Science and Technology Education*, *20*(10). https://doi.org/10.29333/ejmste/15471

Nuradhisti, S. A., & Prasetyanigtyas, F. D. (2025). Development of Mystery Box Learning Media to Improve Elementary School Students' Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *11*(3), 907–916. https://doi.org/10.29303/jppipa.v11i3.10801

Nurhayati, N., & Fathurrohman, F. (2025). Gamification in School Education: A Systematic Review of Its Effectiveness in Improving Student Motivation and Academic Outcomes. *AL-ISHLAH: Jurnal Pendidikan*, *17*(2), 2356–2368. https://doi.org/10.35445/alishlah.v17i2.6516

Ortiz-Rojas, M., Chiluiza, K., Valcke, M., & Bolanos-Mendoza, C. (2025). How gamification boosts learning in STEM higher education: a mixed methods study. *International Journal of STEM Education*, *12*(1). https://doi.org/10.1186/s40594-024-00521-3

Papalazarou, N., Lefkos, I., & Fachantidis, N. (2024). The Effect of Physical and Virtual Inquiry-Based Experiments on Students' Attitudes and Learning. *Journal of Science Education and Technology*, *33*(3), 349–364. https://doi.org/10.1007/s10956-023-10088-3

Partarakis, N., Patsiouras, N., Evdemon, T., Doulgeraki, P., Karuzaki, E., Stefanidi, E., Ntoa, S., Meghini, C., Kaplanidi, D., Fasoula, M., & Zabulis, X. (2021). Enhancing the Educational Value of Tangible and Intangible Dimensions of Traditional Crafts Through Role-Play Gaming. In *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST, 367 LNICST* (pp. 243–254). https://doi.org/10.1007/978-3-030-73426-8_14

Perea, H. R., Piedrahita, A. R., & Alzate, Ó. E. T. (2025). Models of environmental awareness: exploring their nature and role in environmental education – a systematic review. *Heliyon*, *11*(13). https://doi.org/10.1016/j.heliyon.2025.e43679

Pertiwi, T. U., Oetomo, D., & Sugiharto, B. (2024). The Effectiveness of STEM Project-Based Learning in Improving Students' Environmental Literacy Abilities. *JPBI (Jurnal Pendidikan Biologi Indonesia*, *10*(2), 476–85. https://doi.org/10.22219/jpbi.v10i2.33562

Priyani, N. E., & Nawawi, N. (2021). Analisis Pembelajaran STEM di Daerah Terluar Tertinggal Terdepan Indonesia Selama Masa Pandemi. *PSEJ (Pancasakti Science Education Journal)*, *6*(1), 30–37. https://doi.org/10.24905/psej.v6i1.30

Rahman, A. A., Kaniawati, I., Riandi, R., & Hendayana, S. (2023). Secondary Science Teachers Perception on STEM Learning for Sustainable Development. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1297–1303. https://doi.org/10.29303/jppipa.v9i3.2776

Ramadhona, T., Wiyono, K., & Patriot, E. A. (2026). Development of STEM-Based Interactive Learning Media for Critical Thinking Skills in Renewable Energy: Solar Power Plants. *Lontar Physics Today*, *5*(1), 87–113.

https://doi.org/10.26877/lpt.v5i1.360

Reiss, K., & Filtzinger, B. (2023). *STEMplus: The Foundation of an Education in the 21st Century* (p. 15). Retrieved from https://www.siemens-stiftung.org/wp-content/uploads/2023/08/MINT_Bildung_Plus_en-002.pdf

Shao, F., Tang, L., & Zhang, H. (2024). Video watching and hands-on experiments to learn science: what can each uniquely contribute? *Disciplinary and Interdisciplinary Science Education Research*, *6*(1). https://doi.org/10.1186/s43031-024-00103-x

Sharmin, S., Koiler, R., Sadik, R., Bhattacharjee, A., Patre, P. R., Kullu, P., Hohensee, C., Getchell, N., & Barmaki, R. L. (2024). Cognitive Engagement for STEM+C Education nvestigating Serious Game Impact on Graph Structure Learning with fNIRS. *IIEEE International Conference on Artificial Intelligence and EXtended and Virtual Reality (AIxVR)*. https://doi.org/10.1109/AIxVR59861.2024.00032

Suryaningsih, S., & Nurlita, R. (2021). Pentingnya Lembar Kerja Peserta Didik Elektronik (E-LKPD) Inovatif dalam Proses Pembelajaran Abad 21. *Jurnal Pendidikan Indonesia (Japendi)*, *2*(7). https://doi.org/10.36418/japendi.v2i7.233

Tan, L., & Kocsis, A. (2024). Ill-Defined Problems in Wicked Learning Environments. *She Ji*, *10*(4), 456–473. https://doi.org/10.1016/j.sheji.2024.11.004

Vasconcelos, M. A. R., & Dos Santos, R. P. (2023). Enhancing STEM Learning with ChatGPT and Bing Chat as Objects-to-Think-With: A Case Study. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(7). https://doi.org/10.29333/ejmste/13313

Vennix, J., Brok, P., & Taconis, R. (2017). Perceptions of STEM-based Outreach Learning Activities in Secondary Education. *Learning Environments Research*, *20*(1), 21–46. https://doi.org/10.1007/s10984-016-9217-6

Wang, L. H., Chen, B., Hwang, G. J., Guan, J. Q., & Wang, Y. Q. (2022). Effects of digital game-based STEM education on students' learning achievement: a meta-analysis. *International Journal of STEM Education*. https://doi.org/10.1186/s40594-022-00344-0

Widiana, W. (2022). Game Based Learning dan Dampaknya terhadap Peningkatan Minat Belajar dan Pemahaman Konsep Siswa dalam Pembelajaran Sains di Sekolah Dasar. *Jurnal Edutech Undiksha*, *10*(1), 1–10. https://doi.org/10.23887/jeu.v10i1.48925

Wu, H., & Molnár, G. (2022). Analysing Complex Problem-Solving Strategies from a Cognitive Perspective: The Role of Thinking Skills. *Journal of Intelligence*, *10*(3). https://doi.org/10.3390/jintelligence10030046

Yulianci, S., Nurjumiati, N., Asriyadin, A., & Adiansha, A. A. (2021). The Effect of Interactive Multimedia and Learning Styles on Students' Physics Creative Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *7*(1), 87–91. https://doi.org/10.29303/jppipa.v7i1.529

Zhang, L., Basham, J. D., Carter, R. A., & Zhang, J. (2021). Exploring Factors associated with the implementation of student-centered instructional practices in U.S. classrooms. *Teaching and Teacher Education*, *99*, 103273. https://doi.org/10.1016/j.tate.2020.103273

Zhong, Y., Fryer, L. K., Zheng, S., Shum, A., & Chu, S. K. W. (2025). The power of play: integrating competitive sandbox game for experiential learning to foster twenty-first century skills. *International Journal of Educational Technology in Higher Education*, *22*(1). https://doi.org/10.1186/s41239-025-00528-y