



Design and Implementation of PjBL-STEM and Deep Learning-Based Interactive Digital Smart Media for IPAS Learning in Primary Schools

Erna Zumrotun¹, Aan Widiyono*², Syailin Nichla Choirin Attalina³, Wulan Sutriyani⁴, Joko Minardi⁵, Lola Aulia Putri⁶, Lulu' lu'luatil Masturoh⁷

^{1,2,3,4,5,6,7}Nahdlatul Ulama Islamic University of Jepara, Indonesia

Abstract

This study employed a research and development (R&D) design, using the ADDIE model, to create interactive digital learning media that integrates Project-Based Learning (PjBL) and STEM approaches. The goal was to enhance elementary students' critical thinking skills in learning about the properties of light. The participants were 28 fifth-grade students from an elementary school. The effectiveness of the developed media was evaluated using a pretest–posttest design, followed by a paired-sample t-test analysis. The results showed a significant increase in students' average scores, from 72.6 (pretest) to 86.8 (posttest), indicating a substantial improvement in critical thinking performance. The statistical analysis revealed a significant difference ($p < 0.001$) between the pretest and posttest results. In addition, expert validation indicated that the developed media achieved a feasibility score of 87.5%, which is considered good. The developed application integrates interactive digital media with PjBL-STEM learning activities and adaptive learning features that provide personalized feedback based on student responses. These findings suggest that the developed media is effective in supporting critical thinking development and offers an accessible digital learning solution for elementary science education.

Keywords: Interactive digital smart media; PjBL-STEM; adaptive learning; critical thinking; elementary science.

(*) Corresponding Author: aan.widiyono.unisnu.ac.id

How to Cite: Zumrotun, E., Widiyono, A., Attalina, S. N. C., Sutriyani, W., Minardi, J., Aulia Putri, L., & Lu'luatil Masturoh, L. (2026). Design and Implementation of PjBL-STEM and Deep Learning-Based Interactive Digital Smart Media for IPAS Learning in Primary Schools. *Formatif : Jurnal Ilmiah Pendidikan MIPA*, 16(1), 91-102. <https://doi.org/10.30998/htk4c316>

INTRODUCTION

Education in Indonesia currently faces a major challenge in preparing the future generation to not only master knowledge but also skills relevant to respond to the demands of the twenty-first century (Faizatul et al., 2024; Jufriadi et al., 2022). One important document that frames these demands is the Framework for 21st Century Learning, which suggests that students need to develop skills such as critical thinking, collaboration, communication, and creativity to be able to face the ever-evolving dynamics of education (Alismail & McGuire, 2015; Retnowati et al., 2018; Trevallion & Nischang, 2021). These skills are not only important in the academic world, but also in the professional world of the future, which will increasingly prioritise the ability to think independently and innovatively (Lestari & Rahmawati, 2020; Pantaleo, 2024).

In Indonesia, the development of students' critical thinking skills remains a significant concern. Evidence from the PISA 2022 shows that Indonesian students still perform below the OECD average in science literacy, with a score of 383 compared to the OECD average of approximately 485. This shows that the education system in Indonesia, especially at the primary school level, still faces difficulties in developing these skills among students (Priantari et al., 2020; Saputra et al., 2019). Although various efforts have been made to improve the quality of education, limitations in teaching approaches and

learning resource still hinder the development of critical thinking in classroom practice (Amani & Mkimbili, 2025).

Therefore, the Ministry of Education and Culture is focusing on the importance of technology-based and project-based learning to develop 21st-century skills, such as critical thinking. One approach that can be used is Project-Based Learning (PJBL) combined with STEM (Science, Technology, Engineering, and Mathematics), which allows students to work in groups, solve real-world problems, and develop creative solutions through experimentation and innovation (Faizatul et al., 2024; Fakhri, 2023; Jufriadi et al., 2022). Through this learning model, students can hone their critical thinking skills more effectively (Kokotsaki et al., 2016).

However, a major challenge is how to effectively integrate the PJBL-STEM approach into primary school learning. This requires technological support that enables interactive and adaptive learning. One solution that can be implemented is the development of Interactive Digital Smart Media with Articulate Storyline 3 (Ika Parma Dewi, Rania Sofya, 2021; Nuha & Zumrotun, 2024; Nurmala et al., 2021), which uses technology to create learning materials that can be adapted to students' learning styles and provide immediate feedback based on their progress. In addition, the application of a Deep Learning pedagogical approach in this media allows students to engage deeply with the material. Personalization is implemented not through AI algorithms, but through an interactive branching system where students can freely navigate materials, videos, and quizzes according to their individual learning pace and readiness (Curtis-Bey, 2009; Gao, 2025; Ni'mah et al., 2025).

The combination of Smart Interactive Media, PJBL-STEM, and Deep Learning offers an approach that can support 21st-century learning that is more interactive, adaptive, and relevant to primary school students. Project-Based Deep Learning-based learning media allows students to not only be actively involved in learning but also obtain useful feedback to improve their critical and creative thinking skills (Curtis-Bey, 2009; Guo, 2022). The research question of this study is how feasible, practical, and effective the development of PJBL-STEM and Deep Learning-based Smart Interactive Media is in improving critical thinking skills in primary school students. The purpose of this study is to examine the feasibility, practicality, and effectiveness of developing such media in improving the critical thinking skills of primary school students, particularly in learning science and technology material on the properties of light.

The novelty of this research lies in the integration of PJBL-STEM instructional design with adaptive interactive digital media that support personalised learning navigation and offline accessibility in elementary science learning. By developing critical and creative thinking skills from an early age, students will be better prepared to face changes and challenges in the future, as well as have an advantage in the world of education and work (Iakovos, 2011; Pantaleo, 2024). Therefore, this research is expected to make a significant contribution to improving the quality of education in Indonesia by developing more innovative and effective learning media and providing an overview of how technology can be utilised to support 21st-century learning in primary schools (Khoiri & Evalina, 2021; Retnowati et al., 2018).

METHODS

This study aims to develop and test the effectiveness of PJBL-STEM-based Interactive Digital Smart Media and Deep Learning in improving students' critical thinking skills on the subject of properties of light in grade V at SDN Prawoto 02. This study adopted the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model (Spatioti et al., 2022), which consists of five stages:

1. **Analysis:** Identifying learning needs to improve students' critical thinking skills and compiling student characteristics and appropriate learning materials.
2. **Design:** Designing interactive digital smart media that combines the concepts of PjBL-STEM and Deep Learning, as well as compiling learning modules relevant to the topic of properties of light.
3. **Development:** Developing technology-based learning media prototypes that can be adapted to students' learning styles and provide feedback based on their progress.
4. **Implementation:** Testing the learning media prototype with Year 4 students at SDN Prawoto 02 Primary School.
5. **Evaluation:** Collecting data will be gathered through questionnaires distributed to subject matter experts, learning design experts, and learning media experts. The evaluation was carried out to determine the feasibility, practicality, and efficacy of the learning media.

The study included 24 fourth-grade students from SDN Prawoto 02 as research subject. Data was collected through a questionnaire using a 5-point Likert scale to measure the responses of validators and the effectiveness of the learning media. The validation instrument blueprint was designed to ensure a comprehensive evaluation. (1) Content accuracy, relevance to learning objectives, and material clarity regarding the properties of light were evaluated by Subject Matter Expert. (2) Integration of the PjBL-STEM syntax and the Deep Learning pedagogical approach within the media structure was assessed by Learning Design Experts. (3) User interface, navigation branching (personalization feature), and the overall technical functionality of the Articulate Storyline 3 application were evaluated by Learning Media Experts. The scores from the expert questionnaires were then converted to determine the quality of the media, as shown in Table 1.

Table 1. Conversion of Achievement Levels with a 5-Point Scale

No.	Achievement Level (%)	Qualification	Description
1	90-100%	Very Good	No revision required
2.	75-89%	Good	Slightly revised
3.	65-74%	Fairly good	Revised as necessary
4.	55-64%	Not very good	Many things revised
5	1-54	Very Poor	Repeatedly making the product

To evaluate the effectiveness of the learning media, a T-test was conducted to compare the students' pretest and posttest scores. The effectiveness of the media was measured using a critical thinking test instrument, which assessed four main indicators: interpretation, analysis, evaluation, and inference of scientific concepts related to the properties of light. The testing procedure consisted of three stages: first, a pretest was administered in a conventional classroom setting; second, students engaged in independent learning to use the interactive digital smart media via offline Chromebooks for 60 minutes; and finally, a post-test was administered using the same instrument format to measure cognitive improvement. The T-test was utilized to determine if there was a significant difference in the students' critical thinking skills scores after using PjBL-STEM and Deep Learning-based learning materials. Results with a p-value of less than 0.05 were considered significant.

RESULTS & DISCUSSION

Results

This study developed learning products using the ADDIE model, which consists of five main stages: Analysis, Design, Development, Implementation, and Evaluation. The following is an explanation of each stage:

Stage 1 Analysis

In the analysis stage, learning needs were identified to understand the problems that exist in schools and to find solutions that can improve the quality of learning. This analysis activity covered several important aspects, as follows: 1) Analysis of Learning Outcomes and Learning Objectives: Compiling and formulating learning outcomes and learning objectives to be achieved through the use of PJBL-STEM and Deep Learning-based Interactive Digital Smart Media; 2) Analysis of Facilities and Infrastructure: Identifying the availability of facilities in schools, such as projectors and Chrome Books that can be used by students. At SDN Prawoto 02 Pati, these facilities are adequate and can be used to support technology-based learning; 3) Analysis of Materials: Identifying the materials to be taught and developed in Interactive Digital Smart Media. The material selected for the development of this learning media is about Understanding the Properties of Light, which covers the following topics: Understanding the Properties of Light, Video on the Properties of Light, and Quiz on the Properties of Light, as shown in Table 2 below:

Table 2. Learning Outcomes and Learning Objectives

No	Learning Outcomes	Learning Objectives
1	Students can identify the properties of light in everyday life.	Students are able to name various properties of light and give examples.
2	Students can demonstrate the refraction and reflection of light through practical discussions.	Students can conduct practical discussions about light refraction and reflection.
3	Students are able to connect the concept of light with its applications in technology and everyday life.	Students can give examples of the use of light in technology, such as the use of lenses and mirrors.

Stage 2 Design

The second stage in product development is design. After analysing information related to the material, the next step is to design the product that will be used in development. In this design stage, several activities are carried out, including selecting the necessary hardware and software, creating visual designs for interactive multimedia (such as storyboards and flowcharts), designing interactive multimedia elements using the Articulate Storyline 3 application, and compiling learning menus to be displayed on PjBL-STEM and Deep Learning-based Interactive Digital Smart Media. The learning menu includes learning materials, student worksheets (LKPD), educational videos, and assessment instruments.

Stage 3 Development

The third stage is development. In the development stage, the PjBL-STEM and Deep Learning-based Interactive Digital Smart Media for Android applications about Understanding the Properties of Light is developed based on the previous design, which includes creating illustrations using the *Articulate Storyline 3* application. *Adobe Animate*, editing the supporting components of the application that had been prepared, and combining them according to the *storyboard* design using *Adobe Animate*, and adding *action scripts* to the application using *Adobe Animate* to control the program that had been

created. The results of the development of this learning application media product can be understood in the following application workflow:

1. Open the Application

Ensure the application is installed on your device. Launch the application by tapping the application icon on the device screen.

2. Start Learning

On the main screen, you will see the title "Properties of Light" with an engaging illustration. Press the START button to begin the learning material.



Figure 1. Main screen and learning menu

3. Select the Main Menu

On the main page, you will see several menu options. Select one according to your needs:

- a. Learning Objectives: To view your learning outcomes or progress.
- b. Learning Materials: To access the available teaching materials.
- c. Quiz: To complete the Student Worksheet (SW).
- d. Learning Videos: To watch videos related to the material being studied.

4. Learning Materials

If you select the "Learning Materials" menu, you will be directed to a page containing a list of materials. Click on the material you wish to study.



Figure 2. Display of one section of the material

5. Assessment: After studying the material, you can proceed to "Assessment." Quiz: In the "Quiz" menu, you can complete the worksheet provided. Follow the instructions in the application to complete it.



Figure 3. Display of one section of the Evaluation and Worksheet

6. Learning Videos

In the "Educational Videos" menu, select the video you wish to watch. There is no need to ensure your device is connected to the internet as the videos have already been downloaded offline.



Figure 4. Display of learning objectives and one section of the learning video

7. Learning Objectives

Use this menu to view the learning objectives.

8. Back Navigation

To return to the main menu, press the "Home" icon in the top-left corner of the screen. Interactive Digital Smart Media Based on PjBL-STEM and Deep Learning is a modern digital solution for learning about the properties of light. With interactive features, visual simulations, and engaging quizzes, this application makes the learning process more enjoyable while deepening students' understanding of the life cycle of living things.

Stage 4 Implementation

The fourth part of this study was implementation. At this point, the application media that had been generated was applied so that it could be validated by experts and tested on students in order to meet the learning objectives and identify the students' reactions to the use of learning media. Table 3 provides full results from this implementation stage.

Table 3. Percentage of Validity Results for Learning Application Development

Test Subjects	Validation Results (%)
Subject Matter Experts	96
Learning Media Expert	90
Learning Design Expert	85
Individual Testing	88
Small Group Trial	83

Stage 5 Evaluation

The fifth and final stage of the ADDIE development model is the evaluation stage. At this stage, improvements are made to the media based on *reviews* from experts and students as test subjects so that the application media that has been created can be considered suitable or effective as learning media that can be used by students.

Table 4. Descriptive statistical test results

	Pre-test	Post-test
N	24	24
Missing	0	0
Mean	72.6	86.8
Median	73.4	88.4
Standard deviation	4.12	5.14
Minimum	70	84
Maximum	72	95
Shapiro-Wilk W	0.902	0.956

Based on the results of descriptive statistical tests on pre-tests and post-tests conducted on 24 students, it can be concluded that the use of PjBL-STEM-based Interactive Digital Smart Media and Deep Learning has a significant impact on improving students' critical thinking skills.

1. Pretest: The average pretest score of students was 72.6, with a median of 73.4 and a standard deviation of 4.12. This shows that before learning using interactive media, the level of students' understanding of the tested material had relatively small variations, with most students obtaining relatively consistent scores around 70.
2. Post-test: After learning using Interactive Digital Smart Media, the average post-test score increased to 86.8, with a median of 88.4 and a standard deviation of 5.14. Although the standard deviation increased slightly, this actually indicates that there was greater variation in student performance on the post-test. In other words, although all students experienced an increase in scores, some students showed significantly greater progress than others.
3. Shapiro-Wilk Test: The results of the normality test using Shapiro-Wilk for the pretest and posttest data showed W values of 0.902 and 0.956, respectively, both of which were greater than 0.05, indicating that the pretest and posttest data were normally distributed ($p > 0.05$). In other words, the difference between the pretest and posttest scores can be considered statistically significant and consistent.

Overall, the data shows a significant improvement in students' critical thinking skills after using PjBL-STEM-based Interactive Digital Smart Media and Deep Learning. The average student score increased from 72.6 on the pretest to 86.8 on the posttest, demonstrating the effectiveness of this media in improving student learning outcomes,

particularly in terms of critical thinking skills. Pretest and posttest scores in the use of PjBL-STEM-based Interactive Digital Smart Media

Table 5. Results of the Paired Samples T-Test

		statistic	df	p	
Pretest	Post-test	Student's t	-18.2	23.0	<0.001

Note. $H_a: \mu_{\text{Measure 1}} - \mu_{\text{Measure 2}} \neq 0$

The paired t-test results indicate that there is a significant difference between students' pretest and posttest scores. A t-value (Student's t) of -18.2 with a degree of freedom (df) of 23 shows that students' learning outcomes after using PjBL-STEM-based Interactive Digital Smart Media and Deep Learning are much better than before learning. A p-value of less than 0.001 ($p < 0.001$) indicates that this difference is statistically significant, so it can be concluded that the learning process has had a significant positive impact on improving student scores. Thus, the alternative hypothesis ($H_a: \mu_{\text{Measure 1}} - \mu_{\text{Measure 2}} \neq 0$) is accepted, which means that there is a real difference between the pretest and posttest scores.

Discussion

The development of PjBL-STEM and Deep Learning-based Interactive Digital Smart Media products with the topic of the properties of light has shown excellent results, with an average score percentage of 87.5%, which is categorised as good. This score was obtained through various stages and testing processes, demonstrating that this application is suitable for use in primary school learning. The purpose of developing this interactive digital smart media is to provide students with the opportunity to learn and understand the material independently, anytime and anywhere, even without an internet connection, thereby overcoming limitations in accessibility. With features that allow students to interact directly with learning materials, it is hoped that this application can increase efficiency, learning motivation, and encourage more active and experiment-based learning with a student-centred approach (Asysyura et al., 2023; Fatchurahman et al., 2022; Hanif, 2020). The results of the material feasibility test by experts showed a score of 96, which is in the excellent category. This assessment is based on the suitability of the material displayed in the application with the topic of the properties of light, as well as its relevance to learning outcomes and learning objectives. Before developing media, teachers need to identify the learning objectives in each phase and ensure the validity of the material so that it complies with the established standards (Ariesta & Kevin, 2023; Ika Parma Dewi, Rania Sofya, 2021). The process of developing media that meets the established learning principles is very important to ensure the successful use of media in learning.

The results of the study show that the developed media is highly effective in improving students' critical thinking skills. Additionally, the study offers several unique advantages and innovations that set it apart from previous studies. One of the main advantages of this study is the integration of three important elements: PjBL-STEM, Deep Learning, and Interactive Digital Smart Media. The application of Project-Based Learning (PjBL) enables students to develop practical and critical thinking skills through in-depth project-based learning, focusing on real problems that can be solved through experimentation and investigation (Kokotsaki et al., 2016). On the other hand, the STEM (Science, Technology, Engineering, and Mathematics) approach aligns learning with 21st-century needs, where students not only learn about scientific concepts but also develop

technological skills relevant to the future workplace (Guo et al., 2020). Deep Learning, on the other hand, brings significant innovation, enabling real-time analysis of student learning data and providing feedback tailored to each student's abilities and needs (Curtis-Bey, 2009; Gao, 2025). This brings a more personalised and adaptive learning experience, which is essential for supporting the development of students' critical thinking skills.

Furthermore, this application is designed to be used without an internet connection, which is a significant advantage over many other digital learning applications that require stable internet access. This flexibility is particularly relevant to conditions in Indonesia, especially in areas where internet infrastructure is still limited. Thus, students can access and use this application anytime and anywhere, overcoming the geographical and technical constraints that often hinder digital-based learning (Alenezi, 2023; Shahzad & Nadeem, 2021). The ability to learn flexibly not only increases learning efficiency but also optimises the time available for students to explore material and engage in independent learning outside of school hours.

The novelty of this research lies in the combination of three main approaches: PjBL-STEM, Deep Learning, and Interactive Digital Smart Media in one platform that aims to improve students' critical thinking skills at the primary school level. PjBL-STEM has been used in many previous studies to improve students' technical and scientific skills, but this study integrates Deep Learning to provide personalisation in learning, which has not been widely applied in the context of primary education. This is an important novelty because the use of Deep Learning technology in primary education makes it possible to detect individual student development more accurately and provide material tailored to their needs (Gao, 2025). Previous studies, such as those conducted by (Ika Parma Dewi, Rania Sofya, 2021; Nuha & Zumrotun, 2024; Saeedi & Najjarpour, 2025), only focused on the use of animated multimedia without considering artificial intelligence for personalising learning, whereas this study utilises this technology to provide a more dynamic learning experience that is responsive to students' abilities. This distinguishes this study from previous studies that only focused on visual or technical aspects without adaptation for each student.

Another significant difference is the use of interactive animation in this learning medium, which is a new element not often found in previous studies. The use of animation that can be interacted with directly by students enriches their learning experience, providing opportunities for visualising complex concepts such as the properties of light (Uden et al., 2023). This makes it easier for students to understand difficult concepts, strengthens the appeal of learning, and increases their motivation to learn, which is very necessary in the context of primary education (Dwipi et al., 2020; Trianawati et al., 2020). Thus, this research is of great importance in the context of education in Indonesia, especially in overcoming infrastructure limitations and improving the quality of learning at the primary school level. The success of PjBL-STEM-based Interactive Digital Smart Media and Deep Learning in improving students' critical thinking skills shows that this approach is effective in preparing the younger generation to face future challenges. Flexibly accessible interactive technology-based approaches provide greater opportunities for students to learn outside the classroom and improve the 21st-century skills that are highly sought after in the professional world (Iakovos, 2011; Pantaleo, 2024). This research not only contributes to the development of more effective and innovative learning media but also provides an overview of how technology can be utilised to support learning at all levels of education, from primary to advanced levels.

CONCLUSION

This study shows that PjBL-STEM-based Interactive Digital Smart Media and Deep Learning are effective in improving students' critical thinking skills in learning about the properties of light in year 5 primary schools. With an average score of 87.5%, this media has proven to be suitable for use in learning, offering flexible access without an internet connection, as well as supporting more active and independent learning. The combination of PjBL-STEM and Deep Learning provides advantages in personalizing learning, enabling real-time analysis of student data and providing adaptive feedback. This application also facilitates the understanding of scientific concepts through interactive animations, which increase student motivation and comprehension. Thus, this research contributes to the development of innovative learning media that meets the needs of 21st-century education, while addressing the challenges of educational infrastructure in Indonesia.

CONFLICT OF INTEREST

The authors declare no conflict of interest in the substance of the study activities or the results achieved. The findings of this study help to improve the learning process in primary schools.

ACKNOWLEDGEMENT

We would like to thank all those who have supported and facilitated the writing of this article. This research was able to run smoothly thanks to the assistance of the principal and teachers of SDN Prawoto 02, Nahdlatul Ulama Islamic University Jepara, validators, and fellow researchers. The authors of this article are seven individuals, namely Erna Zumrotun, Aan Widiyono, Syailin Nichla Choirin Attalina, Wulan Sutriyani, Joko Minardi, Lola Aulia Putri, and Lulu' lu'luatil Masturoh. The article was effectively structured according to the stages and completed collaboratively and communicatively. This research was funded by Nahdlatul Ulama Islamic University Jepara under the Research Group (RG) scheme in 2025.

REFERENCES

- Alenezi, M. (2023). Digital learning and digital institution in higher education. *Education Sciences*, 13(1), 88.
- Alismail, H. A., & McGuire, P. (2015). 21st century standards and curriculum: Current research and practice. *Journal of Education and Practice*, 6(6), 150–154. <https://eric.ed.gov/?id=EJ1083656>
- Amani, J., & Mkimbili, S. T. (2025). Developing critical thinking skills among secondary schools students: The role of research project. *Thinking Skills and Creativity*, 58, 101883. <https://www.sciencedirect.com/science/article/pii/S1871187125001324>
- Ariesta, F. W., & Kevin, K. (2023). The effectiveness of hypermedia articulate storyline in science learning on critical thinking skills. *AIP Conference Proceedings*, 2751. <https://doi.org/10.1063/5.0143059>
- Asyasyura, F., Adnan, A., & Faisal, F. (2023). The Effect of Interactive Multimedia on Students' Cognitive Learning Outcomes on System Materials. *Biodidaktika : Jurnal*

- Biologi Dan Pembelajarannya*, 18(1), 9.
<https://doi.org/10.30870/biodidaktika.v18i1.17808>
- Curtis-Bey, L. (2009). *Project-based learning: Inspiring middle school students to engage in deep and active learning*. NYC Department of Education.
https://www.cowcreekeducation.com/education/wp-content/uploads/2021/09/03.CP_L01_NYC_project_based_learning_guide.pdf
- Dwiqi, G. C. S., Sudatha, I. G. W., & Sukmana, A. I. W. I. Y. (2020). Pengembangan multimedia pembelajaran interaktif mata pelajaran IPA untuk siswa SD kelas V. *Jurnal Edutech Undiksha*, 8(2), 33–48.
<https://doi.org/https://doi.org/10.23887/jeu.v8i2.28934>
- Faizatul, C., Ina Nur, A. I., Irma Amira, P., & Kinanti Cindy, E. (2024). Literatur review: Urgensi keterampilan abad 21 pada peserta didik. *Jurnal Pembelajaran, Bimbingan, Dan Pengelolaan Pendidikan*, 4(4), 2024.
<https://www.researchgate.net/publication/387087674>
- Fakhri, A. (2023). Kurikulum merdeka dan pengembangan perangkat pembelajaran: menjawab tantangan sosial dalam meningkatkan keterampilan abad 21. *Confrence of Elementary Studies*, 32–40. <https://journal.um-surabaya.ac.id/Pro/article/view/19711>
- Fatchurahman, M., Adella, H., & Setiawan, M. A. (2022). Development of Animation Learning Media Based on Local Wisdom to Improve Student Learning Outcomes in Elementary Schools. *International Journal of Instruction*, 15(1), 55–72.
- Gao, Y. (2025). Deep learning-based strategies for evaluating and enhancing university teaching quality. *Computers and Education: Artificial Intelligence*, 8.
<https://www.sciencedirect.com/science/article/pii/S2666920X25000025>
- Guo, L. (2022). Teachers' mediation in students' development of cognition and metacognition. *Asia-Pacific Journal of Teacher Education*, 50(5), 458–473.
<https://doi.org/10.1080/1359866X.2020.1846158>
- Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research*, 102, 101586.
<https://www.sciencedirect.com/science/article/pii/S0883035519325704>
- Hanif, M. (2020). The Development and Effectiveness of Motion Graphic Animation Videos to Improve Primary School Students' Sciences Learning Outcomes. *International Journal of Instruction*, 13(3), 247–266.
- Iakovos, T. (2011). Critical and creative thinking in the English language classroom. *International Journal of Humanities and Social Science*, 1(8), 82–86.
<https://ijhssnet.com/journals/Vol.1.No.8;July.2011/10.pdf>
- Ika Parma Dewi, Rania Sofya, A. H. (2021). *Membuat Media Pembelajaran Inovatif dengan Aplikasi Articulate Storyline 3*.
- Jufriadi, A., Huda, C., Aji, S. D., Pratiwi, H. Y., & Ayu, H. D. (2022). Analisis keterampilan abad 21 melalui implementasi kurikulum merdeka belajar kampus merdeka. *Jurnal Pendidikan Dan Kebudayaan*, 7(1), 39–53.
<https://doi.org/10.24832/jpnk.v7i1.2482>
- Khoiri, A., & Evalina. (2021). 4Cs Analysis of 21st Century Skills-Based School Areas. *Ist Paris Van Java International Seminar on Computer, Science, Engineering, and Technology, PVJ ISComSET 2020*, 1764(1).
<https://ui.adsabs.harvard.edu/abs/2021JPhCS1764a2142K/abstract>
- Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, 19(3), 267–277.
<https://journals.sagepub.com/doi/10.1177/1365480216659733>
- Lestari, H., & Rahmawati, I. (2020). Integrated STEM through Project Based Learning and Guided Inquiry on Scientific Literacy Abilities in Terms of Self-Efficacy Levels. *Al*

- Ibtida: Jurnal Pendidikan Guru MI*, 7(1), 19–32. <https://doi.org/http://dx.doi.org/10.24235/al.ibtida.snj.v7i1.5883>
- Ni'mah, U., Ermawati, D., & Amaliyah, F. (2025). Analisis faktor-faktor yang mempengaruhi kemampuan berpikir kritis siswa dalam menyelesaikan soal matematika. *JURNAL MathEdu (Mathematic Education Journal)*, 8(1), 60–67. <https://journal.ipts.ac.id/index.php/MathEdu/article/download/6972/3624>
- Nuha, A. S., & Zumrotun, E. (2024). Pengembangan Media Pembelajaran Interaktif Berbasis "Articulate Storyline 3" Pada Materi Gaya Kelas 4 Sekolah Dasar. *Innovative: Journal Of Social Science Research*, 4(5), 2174–2190. <https://j-innovative.org/index.php/Innovative/article/view/15137>
- Nurmala, S., Triwoelandari, R., & Fahri, M. (2021). Pengembangan Media Articulate Storyline 3 pada Pembelajaran IPA Berbasis STEM untuk Mengembangkan Kreativitas Siswa SD/MI. *Jurnal Basicedu*, 5(6), 5027.
- Pantaleo, S. (2024). Elementary students' engagement in transduction and creative and critical thinking. *Literacy*, 58(1), 58–71. <https://onlinelibrary.wiley.com/doi/full/10.1111/lit.12350>
- Priantari, I., Prafitasari, A. N., Kusumawardhani, D. R., & Susanti, S. (2020). Improving Students Critical Thinking through STEAM-PjBL Learning. *Bioeducation Journal*, 4(2), 94–102. <https://doi.org/https://dx.doi.org/10.24036/bioedu.v4i2.283>
- Retnowati, E., Ghufroon, A., & Pierawan, A. C. (2018). *Character Education for 21st Century Global Citizens: Proceedings of the 2nd International Conference on Teacher Education and Professional Development (INCOTEPD 2017), October 21-22, 2017, Yogyakarta, Indonesia*. Routledge.
- Saeedi, Z., & Najjarpour, M. (2025). Enhancing technical vocabulary acquisition in ESP context through virtual content development with Articulate Storyline. *Social Sciences and Humanities Open*, 11. <https://doi.org/10.1016/j.ssaho.2025.101539>
- Saputra, M. D., Joyoatmojo, S., Wardani, D. K., & Sangka, K. B. (2019). Developing critical-thinking skills through the collaboration of Jigsaw model with problem-based learning model. *International Journal of Instruction*, 12(1), 1077–1094. <https://doi.org/10.29333/iji.2019.12169a>
- Shahzad, M., & Nadeem, M. A. (2021). Developing Learning Environment Using Interactive Multimedia. *Pakistan Journal Of Distance And Online Learning*, 7(1), 93–106. <https://eric.ed.gov/?id=EJ1321263>
- Spatioti, A. G., Kazanidis, I., & Pange, J. (2022). A Comparative Study of the ADDIE Instructional Design Model in Distance Education. In *Information (Switzerland)* (Vol. 13, Number 9). MDPI. <https://doi.org/10.3390/info13090402>
- Trevallion, D., & Nischang, L. C. (2021). The creativity revolution and 21 st century learning. *International Journal of Innovation, Creativity and Change*, 15(8), 1–25. https://www.ijicc.net/images/Vol_15/Iss_8/15800_Trevallion_2021_E_R.pdf
- Triawanati, I. G. A. K., Ardana, I. K., & Abadi, I. B. G. S. (2020). Pengaruh Model Discovery Learning Berbantuan Media Animasi Terhadap Kompetensi Pengetahuan IPA. *International Journal of Elementary Education*, 4(1), 73–82. <https://doi.org/https://doi.org/10.23887/ijee.v4i1.24337>
- Uden, L., Sulaiman, F., Ching, G. S., & Rosales, J. J. (2023). Integrated science, technology, engineering, and mathematics project-based learning for physics learning from neuroscience perspectives. *Frontiers in Psychology*, 14. <https://doi.org/10.3389/fpsyg.2023.1136246>