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Effectiveness of the Creative-Scientific Decision-Making Skills Model (CSDMS) Based on Articulate Storyline to Improve Students' Critical Thinking and Scientific Creativity

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Abstract: The conventional learning process makes students easily bored during lessons, so their critical thinking skills and scientific creativity end up being low. Therefore, teachers need to create a learning model that's engaging and can boost students' motivation to learn, so their critical thinking skills and creativity improve as well. This study aims to find out how effective the Creative-Scientific Decision-Making Skills (CSDMS) model based on Articulate Storyline is in enhancing students' critical thinking skills and scientific creativity through science lessons. The research sample consisted of 28 students from SMP Negeri 3 Jorlang Hataran for a limited trial, and 56 students for a broader trial (SMP Negeri 025 Siborutorop and SMP Negeri 2 Lima Puluh Pesisir). This study is a development research (R&D) using the ADDIE model. This study used a One Group Pre-test – Post-test design. The data analysis technique in this research was by comparing students' pre-test and post-test scores using normalized gain (n-gain). It was concluded that the CSDMS model is considered effective in improving students' critical thinking skills and scientific creativity. The study results showed that the average n-gain for critical thinking skills in the limited trial was 0.83, categorized as high, and in the wide trial it was 0.92, categorized as high. Meanwhile, the average scientific creativity of students in the limited trial was 0.71, categorized as high, and in the wide trial it was 0.73, categorized as high. It was concluded that the CSDMS model is considered effective in enhancing students' critical thinking skills and scientific creativity. The challenges faced in this research are limited time, an inadequate internet connection, and the e-module in using the Articulate Storyline application still needs some minor revisions.

Keywords: Articulate Storyline; Creative-Scientific Decision-Making Skills Critical Thinking; Critical Thinking; Effectiveness; Scientific Creativity.

Introduction

Currently, the world is in the era of the 4.0 revolution, and is even about to enter society 5.0, which fundamentally changes the way humans live (Boadu et al., 2025; Usman et al., 2023). This era is marked by the rapid development of technology, which brings changes to life systems such as the education system in Indonesia significantly (Siagian & Aprido, 2023). The era of the 4.0 revolution also challenges the advancement of better education in the future (Manalu & Wilujeng, 2025). In facing this era, educators are required to have knowledge, attitudes, and skills in using technology, think critically, creatively, and be able to teach holistically (Sari et al., 2023).

The quality standards of education in Indonesia will continue to develop over time (Rizki et al., 2021). The current development of education quality in

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Indonesia is already heading towards higher-order thinking skills, often referred to as High Order Thinking (Putri et al., 2023). This development is influenced by global free competition that aims to produce professionals who are creative and capable of making decisions (Salhuteru et al., 2025a). The global free competition has opened up competition among professionals from all over the world (Rahardhian, 2022). People who are less capable than others around the world will be pushed out of their positions, making this a global challenge for everyone (Rea et al., 2024). This global challenge has become a stimulus for the development of education in Indonesia to be oriented towards higher-order thinking.

Higher-order thinking skills involve the ability to think and learn, so education is adjusted to meet the demands of facing challenges in local, national, and global life (Rukmana & Salirawati, 2024). Education should pay attention to thinking abilities to face the demands of the working world, the development of science, technology, and arts, as well as the dynamics of global developments (Alfisyahrani et al., 2025). These thinking skills can be trained, for example, by practicing critical thinking and scientific creativity (Salhuteru et al., 2025b). Critical thinking skills and scientific creativity are very important to train in students so they can solve problems in real life (Jumanto et al., 2024). Critical thinking skills and scientific creativity have become something really important to practice because they can sharpen cognitive abilities and help solve real-life problems (Rizki et al., 2021).

The emergence of the 4.0 revolution has encouraged education experts to integrate technology into learning, referred to as education 4.0 (Ferawati Burhanuddin & Pharmacista, 2023). This indicates that the use of technology in learning activities must become a concrete action at all levels of education (Köse, 2025). The use of technology in learning creates educators who use sophisticated learning media (George & Hovan George, 2024). The rapid development and use of technology will result in the replacement of human roles in the workforce (Kumar et al., 2025). The technology from the industrial revolution 4.0 will replace 52.6 types of jobs that currently exist (Sah et al., 2024). Similarly, data from the U.S. Department of Labor predicts that in the future, as many as 65% of students will work in jobs that do not currently exist (Nurainia & Apriadi, 2025). Thus, education is expected to be able to produce graduates who are skilled, critical, creative, able to solve problems, and able to work using technology in the future (Reyes Domínguez et al., 2024).

The era of the 4.0 revolution, alongside the use of technology, also requires high-level thinking skills, which are competencies in thinking and learning to face the challenges of changes in local, national, and global life (Ontiveros et al., 2025). These thinking competencies can be enhanced by training critical thinking skills and scientific creativity (Wibowo et al., 2024). Critical thinking skills are skills used logically and creatively to assess various information obtained with the aim of analyzing, evaluating, and ultimately reaching the correct conclusions (Fadillah et al., 2025). A person who has critical thinking will achieve higher learning outcomes compared to one with low skills (Wahyuni et al., 2019). This is because critical thinking is reasonable and reflective thinking that focuses on deciding what should be believed or done through observing, analyzing, synthesizing, and concluding according to the facts. A person who has critical thinking skills can be said to be able to use their mind to think at an abstract level, be open to everything, and be able to communicate effectively with others (Fernando Siagian, Muktar Panjaitan, Aprido Bernando Simamora, et al., n.d.).

Likewise, scientific creativity is an ability that a person must have to think from different perspectives and bring their imagination to life in generating new ideas that are used to solve a problem (Syarifatul luthfia, 2024). Creative thinking is also considered a very important skill that must be enhanced by all students to solve a problem (Arini et al., 2017). This is in line with Trianggono's (Trianggono, 2017) opinion, which states that creative thinking skills are the abilities a person must have to think from different perspectives and bring their imagination to life to generate new ideas used to solve a problem. Learning in the 21st century must be built with an educational vision that integrates technology to produce creative thinking ((*Lorin W. Anderson, David R. Krathwohl-A Taxonomy for Learning Teaching and Assessing_ a Revision of Bloom`s Taxonomy of Educational Objetives-Longman (2001)*, n.d.)).

Creativity is a substance that comes from useful new ideas (Widiana & Jampel, 2016). Creativity is creating, constructing, producing, generating, seeing the future, or the ability to analyze the needs of society and the ability to preserve nature (Mynbayeva et al., 2016). (Daly et al., n.d.)view creativity as one of the 'multiple intelligences'. According to (Fernando Siagian, Muktar Panjaitan, Aprido Simamora, et al., n.d.), creativity is intelligence that develops in children in the form of attitudes, habits, and actions in bringing forth something new and original. Without creativity, students will only learn in a narrow cognitive aspect. The creative aspect can explain abstract concepts, thereby allowing for broader mastery.

Creative thinking is essentially a combination of logical thinking and divergent thinking based on intuition. Divergent thinking will produce many ideas, and the truth of that thinking will be determined by logical thinking. Creative thinking is synonymous with divergent thinking. There are four indicators of creative

thinking, namely: (1) fluency, which is the ability to generate many ideas; (2) flexibility, which is the ability to produce varied ideas or methods; (3) originality, which is the ability to produce new ideas that did not exist before; (4) elaboration, which is the ability to develop or add ideas so that more detailed and thorough ideas are produced (Tamrin et al., 2025). Humans who are able to present many ideas or concepts in solving a problem are engaging in creative thinking.

The era of the 4.0 revolution also emphasizes that in the learning process, a vision of educating must be developed by integrating technology to produce critical and creative thinking (Ferdianto et al., 2025). One of the technologies that fosters critical and creative thinking is by using Articulate Storyline (Cırıt & Aydemir, 2023). Articulate Storyline is software that functions as a communication or presentation medium with complete features like Flash, allowing the creation of animations in learning (Jumadi et al., 2021). Therefore, the implementation of Articulate Storyline is a technology that helps bridge the gap between the real world and the virtual world in applying the learning approach.

Research related to critical thinking and scientific creativity has actually been increasing from year to year (Khoiri et al., 2023; Tamrin et al., 2025). Nevertheless, the tendency of achieving critical thinking and creativity among Indonesian students based on the results of the 2022 Program for International Student Assessment (PISA) places Indonesia at rank 69 or the 12th lowest position with a score of 1,108 (Dewi et al., 2025). The reality in the field shows that students' critical thinking and creativity are still considered very low (Mustaqim et al., 2024). As many as 90.5% of students have difficulty applying critical thinking skills to solve problems, and similarly, in terms of creativity, 86.25% of students have difficulty using science knowledge to improve product quality, especially in designing products creatively (Fongkanta & Buakanok, 2024). Based on the preliminary study conducted at the junior high school level, particularly in Pematangsiantar, the average critical thinking skills of students at a moderate level category were 28.47%, with the rest in the low-level category. Likewise, for students' scientific creativity, 26.80% were at the moderate level category, and the rest were in the low category.

The use of learning models is a solution for improving students' critical and creative thinking skills. The learning models that are currently widely used are the PBL and PjBL models (A. F. Siagian et al., 2022, 2023). These PBL and PjBL models can boost students' interest in learning, making them more active in lessons, which in turn increases their critical and creative thinking (Panjaitan et al., 2025). The same goes for teachers; by applying PBL and PjBL models, teachers can explore more knowledge to share with their students (G. Siagian et al., n.d.). However, the PBL model has some weaknesses, namely: it provides less feedback in learning, so the role of students is not maximized, it is less connected to the essence of contemporary science and its applications, and also less helpful in fostering students' critical and creative scientific thinking for generating new ideas (Al-Said et al., 2024; Panjaitan & Siagian, 2020). Similarly, the PjBL model has weaknesses: students will only master a specific topic, and the learning is less meaningful, where students become less motivated if faced with a complicated project (Darmawansah & Puspitasari, 2024; Syahfitri & Muntahanah, 2024).

Based on technological developments in the era of the 4.0 revolution, students must be exposed to technology (Mubarok et al., 2023). One technology used is Articulate Storyline, a multimedia technology application that has the capability to describe an object where visualization is not only seen from one perspective but from all angles because it has three dimensions and still takes into account the physical properties (Kuncoro et al., 2025). Similarly, learning models should be developed based on a model with syntax that intentionally enhances students' critical thinking and creativity skills. The Creative-Scientific Decision-Making Skills (CSDMS) science learning model based on Articulate Storyline is one such model that intentionally boosts students' critical thinking and creativity.

This study aims to produce an effective Creative-Scientific Decision-Making Skills (CSDMS) learning model that can be used to train students' critical thinking and creativity skills. The model referred to is the Creative-Scientific Decision-Making Skills (CSDMS) model. The researcher developed the CSDMS model based on theoretical studies and empirical evidence from the PBL learning model and the DEAL cycle model. Based on the synthesis of previous research on the application of the PBL model and the DEAL cycle model to train students' critical thinking and scientific creativity skills, the researcher believes that several syntaxes need to be applied in the learning model, including: 1) problem orientation; 2) creative exploration; 3) creative elaboration; 4) developing group investigation; 5) solidifying decision making; 6) evaluation and reflection.

Method

The type of research used is development research (Research and Development), commonly abbreviated as R & D. Development research is a research method used to produce a specific product and test the effectiveness of the product that has been developed. The products developed in research are not always physical objects or

hardware, but can also be software. Preparing instruments is a step that connects the definition stage with the design stage. Instrument preparation is carried out by creating validation sheets for expert validators and preparing critical thinking test instruments and taking scientific creativity (Saralee et al., 2024). The validation sheet instruments are designed to see the effectiveness of the developed model. The prepared validation sheets include content validity, construct, and language sheets. To see the effectiveness of the developed model, a critical thinking and scientific creativity instrument was prepared (Yildiz & Guler Yildiz, 2021). Development research has several models, but in this study, the researcher used the ADDIE model developed by Dick and Carry in 1996. The ADDIE model consists of several stages: analysis, design, development, implementation, and evaluation. Each stage in the ADDIE model is interconnected and interacts with each other because each stage can serve as a reference for developing the next stage. Desain development research phases ADDIE model can see in Figure 1.

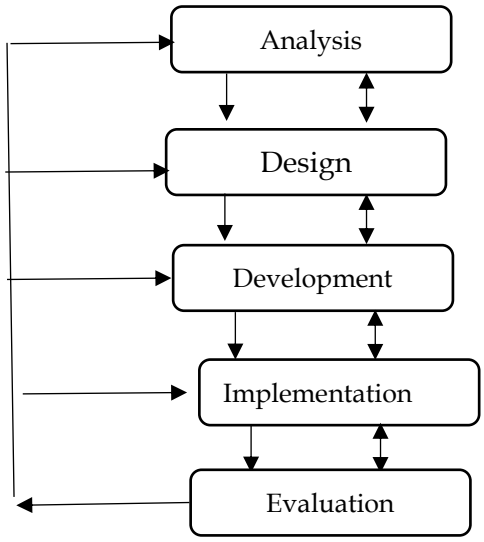

Figure 1. Development research phases ADDIE Model

This research method is pre-experimental with a one-group pretest-posttest design through the application of the Creative-Scientific Decision-Making Skills (CSDMS) model. The population in this study was junior high school students totaling 84 students. The data were analyzed descriptively with pre-test and post-test data analysis using the paired t-test for the limited trial, and the independent t-test for the wide trial. The wide trial design of the CSDMS model was carried out using a one-group pre-test and post-test design. The data analysis technique in this research is by comparing the students' pre-test and post-test scores using normalized gain (n-gain). N-gain shows the improvement in creative thinking skills and decision-making skills test calculated using the formula:

$$< g > = \frac{S_{posttest} - S_{pretest}}{S_{max} - S_{pretest}} \quad (1)$$

The n-gain categories of students' critical thinking skills and scientific creativity as shown in Table 1.

Table 1. Criteria normalized gain <g>

Scor <g>	Criteria <g>
g >0.70	High
$0.30 \leq g \leq 0.70$	Medium
g <0.30	Slow

(Hake, 1999)

Result and Discussion

Critical Thinking Skills
Limited Trial

The results of the limited trial, by comparing pre-test and post-test scores, are in Table 2.

Table 2. Improvement score (n-gain) of critical thinking skills indicators in limited trial

Indicator critical thinking skills	Pre-test Scor	Post-test Scor	n-Gain	Criteria
Actual	55.30	79.30	0.88	High
Reason	53.50	77.50	0.83	High
Argumentation	52.20	76.20	0.79	High
Inference	54.50	80.10	0.91	High
Implication	50.30	76.20	0.76	High
Average	53.16	77.86	0.83	High

Table 2 shows that the average n-gain in student critical thinking skills indicators is 0.83 with a high category. This indicates an improvement in critical thinking skills after implementing the CSDMS model.

Wide Trial

The results of the wide trial, by comparing pre-test and post-test scores, are in Table 3.

Table 3. Improvement score (n-gain) of critical thinking skills indicators in wide trial

Indicator Critical Thinking Skills	Pre-test Scor	Post-test Scor	n-Gain	Criteria
Actual	51.20	84.80	0.98	High
	51.20	84.80	0.92	High
Reason	53.60	84.80	0.98	High
	51.40	82.30	0.89	High
Argumentation	48.70	84.70	0.93	High
	51.40	83.40	0.91	High
Inference	49.60	80.10	0.97	High
	50.40	85.60	0.95	High
Implication	51.30	80.70	0.86	High
	51.40	81.80	0.86	High
Average	51.02	83.30	0.92	High

Table 3 shows that the average n-gain in student critical thinking skills indicators is 0.92 with a high category. This indicates an improvement in critical thinking skills after implementing the CSDMS model.

The effectiveness of a model is related to how effective the model and supporting tools are on learning outcomes (Nieveen & Akker, 2007). The effectiveness of the CSDMS model can be seen from the improvement in critical thinking skills. Data on the improvement of thinking skills were obtained by analyzing the n-gain of pre-test and post-test for each indicator, namely: (1) actuality, (2) reason, (3) argumentation, (4) inference, (5) implication. In general, the improvement in students' critical thinking skills falls into the high category, although the implication indicator obtained the smallest n-gain. This indicates that in classroom learning, implication is rarely applied.

Scientific Creativity
Limited Trial

The results of the limited trial, by comparing pre-test and post-test scores, are in Table 4.

Table 4. Improvement Score (n-gain) of Scientific Indicators in Limited Trial

Indicator scientific creativity	Pre-test Scor	Post-test Scor	n-Gain	Criteria
Fluency	35.00	83.10	0.74	High
Flexibility	30.60	78.80	0.72	High
Originality	39.40	80.00	0.67	Medium
Elaboration	20.60	80.50	0.74	High
Average	31.40	80.60	0.71	High

Table 4. shows that the average n-gain on the students' creative thinking skills indicator is 0.71 with a high category.

Wide Trial

The results of the wide trial, by comparing pre-test and post-test scores, are in Table 5.

Table 5. Improvement score (n-gain) of scientific indicators in wide trial

Indicator Scientific Creativity	Pre-test Scor	Post-test Scor	n-Gain	Criteria
Fluency	30.00	84.40	0.80	High
	28.80	80.40	0.77	High
Flexibility	33.20	81.30	0.72	High
	37.60	83.80	0.74	High
Originality	40.60	80.00	0.66	Medium
	41.90	78.80	0.63	Medium
Elaboration	30.10	82.50	0.75	High
	28.80	81.30	0.77	High
Average	33.87	81.56	0.73	High

Table 5. shows that the average n-gain on the students' creative thinking skills indicator is 0.73 with a high category. The implementation of the CSDMS model in limited trials and wide trials gave an impact on increasing students' scientific creativity. Learning with the CSDMS model is student-centered, so creative thinking skills increase significantly (Zhang., et al., 2020). Creative thinking skills on the originality indicator were low compared to the indicators of fluency, flexibility, and elaboration. After analysis, the reason was found that students had difficulty finding original answers because they were not trained and still depended on their peers' answers.

The effectiveness of the CSDMS model can be seen from the improvement of students' scientific creativity through limited trials and wide trials. Data on the improvement of students' scientific creativity skills were obtained by analyzing the n-gain of pre-test and post-test scores for each indicator, namely: (1) fluency, (2) flexibility, (3) originality, (4) elaboration. Students' scientific creativity experienced improvement with high criteria. The CSDMS model provides a learning environment that allows students to actively engage in developing their scientific creativity during the learning process. This is because the CSDMS model gives students the opportunity to enhance their scientific creativity achievements, which is reflected in its syntax.

Conclusion

Based on the results of the development research and the implementation results, it can be concluded that the Creative-Scientific Decision Making Skills (CSDMS) Model based on Articulate Storyline that was developed is effective, because: a) the average n-gain score for critical thinking skills in the limited trial was 0.83, categorized as high, and in the extensive trial, the n-gain was 0.92, also categorized as high, which indicates that the n-gain value falls into the high criteria (n-gain ≥0.7); b) the average scientific creativity of students in the limited trial had an n-gain of 0.71 with high criteria, and in the extensive trial, the n-gain was 0.73, also high, showing that the n-gain value meets the high criteria (n-gain ≥0.7). The CSDMS model supported by Articulate Storyline presents interesting material that suits learners' needs and leads to technology-based learning. The CSDMS learning model also applies concepts in daily life, which makes students more enthusiastic about learning and makes it easier for them to understand the lesson material. The implication of this research is that the application of the CSDMS model for critical thinking skills, based on the n-gain value indicator, is still low, so further research is needed to reach a high category. The implication of the research on the application of the CSDMS model for scientific creativity shows that the

originality indicator is still in the medium category, so further research is needed to reach a high category. The development of the CSDMS model based on articulate storyline faced obstacles that became the researcher's limitations, namely unstable internet network issues on the phones and laptops used by the students.

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The authors declared that there are no conflicts of interest.

References

Alfisyahrani, Tindangen, M., & Candra, K. P. (2025). Development of Articulate Storyline Media on Biodiversity Content Featuring Tropical Rainforests to Enhance Students' Critical and Creative Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 537–544. https://doi.org/10.29303/jppipa.v11i1.9727

Al-Said, K., Berestova, A., Ismailova, N., & Pronkin, N. (2024). The impact of video-based virtual reality training on critical thinking and cognitive load. *International Journal of Evaluation and Research in Education*, *13*(5), 3239–3247. https://doi.org/10.11591/ijere.v13i5.28109

Arini, W., Asmila, A., & Lubuklinggau, S.-P. (2017). Analisis Kemampuan Berpikir Kreatif Pada Materi Cahaya Siswa Kelas Viii Smp Xaverius Kota Lubuklinggau. *Science and Physics Education Journal (SPEJ)*, *1*(1).

Boadu, D. O., Boafo, F., Owusu-Ansah, L. A., & Mensah, S. (2025). AI and VR-Powered Interventions for Social Anxiety. *International Journal of Virtual and Augmented Reality*, *7*(1), 1–27. https://doi.org/10.4018/ijvar.367871

Cırıt, D. K., & Aydemir, S. (2023). Online scratch activities during the COVID-19 pandemic: Computational and creative thinking. *International Journal of Evaluation and Research in Education*, *12*(4), 2111–2120. https://doi.org/10.11591/ijere.v12i4.24938

Daly, A., Ruxton, S., & Schuurman, M. (n.d.). *Challenges To Children's Rights Today: What Do Children Think?*

Darmawansah, & Puspitasari, D. (2024). Exploring Project-Based Learning in the SVVR Environment: An Epistemic Network Analysis of Pre-service EFL Teachers. *Script Journal: Journal of Linguistics and English Teaching*, *9*(1), 96–111. https://doi.org/10.24903/sj.v9i1.1608

Dewi, T. M., Marwoto, P., Nugroho, S. E., & Muhiri, M. (2025). Teachers' Perceptions Toward Electronic Student Worksheet Based on Waste Treatment Projects to Improve Students' Creative Thinking Skills. *Journal of Innovation in Educational and Cultural Research*, *6*(3), 511–519. https://doi.org/10.46843/jiecr.v6i3.1801

Fadillah, M. A., Tanjung, Y. I., Usmeldi, & Festiyed. (2025). Unveiling the role of critical thinking in education: regional analysis and predictive factors. *International Journal of Evaluation and Research in Education*, *14*(4), 2640–2651. https://doi.org/10.11591/ijere.v14i4.33234

Ferawati Burhanuddin, S., & Pharmacista, G. (2023). Transformation of Companies and Trade in the Era of Society 5.0. In *International Journal of Science and Society* (Vol. 5, Number 5). http://ijsoc.goacademica.com

Ferdianto, F., Mulyatna, F., & Untarti, R. (2025). The Profile of Creative Thinking Process: Prospective Mathematics Teachers-NonCommercial-ShareAlike 4.0 International License (CC BY-NC-SA 4.0). In *Jurnal Eduscience (JES)* (Vol. 12, Number 2).

Fernando Siagian, A., Muktar Panjaitan, Mp. B., Aprido Bernando Simamora, Mp., Dumaris Silalahi, Mp. E., Donni Andreas Nainggolan, Mp., & Nuri Ramadhan, Mp. (n.d.). *KETERAMPILAN BERPIKIR KRITIS CV BRAVO PRESS INDONESIA*. Retrieved www.bravopress.id

Fernando Siagian, A., Muktar Panjaitan, Mp. B., Aprido Simamora, Mp. B., Dumaris Silalahi, Mp. E., & Donni Andreas Nainggolan, Mp. (n.d.). *CV BRAVO PRESS INDONESIA*. Retrieved www.bravopress.id

Fongkanta, P., & Buakanok, F. S. (2024). Development novice teachers' higher-order thinking skills through online problem-based learning platform: A mixed methods experimental research. *Cakrawala Pendidikan*, *43*(3), 756–764. https://doi.org/10.21831/cp.v43i3.72338

George, A. S., & Hovan George, A. S. (2024). Towards a Super Smart Society 5.0: Opportunities and Challenges of Integrating Emerging Technologies for Social Innovation. *Partners Universal International Research Journal*. https://doi.org/10.5281/zenodo.11522048

Jumadi, J., Perdana, R., Hariadi, M. H., Warsono, W., & Wahyudi, A. (2021). The impact of collaborative model assisted by Google Classroom to improve students' creative thinking skills. *International Journal of Evaluation and Research in Education*, *10*(2),396–403. https://doi.org/10.11591/ijere.v10i2.20987

Jumanto, J., Sa'Ud, U. S., & Sopandi, W. (2024). Development of IPAS Teaching Materials with the RADEC Model Based on Metacognitive Strategies to Enhance Critical and Creative Thinking Skills of Elementary School Students. *Jurnal Penelitian Pendidikan IPA*, *10*(3), 1000–1008. https://doi.org/10.29303/jppipa.v10i3.7010

Khoiri, N., Ristanto, S., & Kurniawan, A. F. (2023). Project-Based Learning Via Traditional Game In Physics Learning: Its Impact On Critical Thinking, Creative Thinking, And Collaborative Skills. *Jurnal Pendidikan IPA Indonesia*, *12*(2), 286–292. https://doi.org/10.15294/jpii.v12i2.43198

Köse, E. (2025). Society 5.0 in business management: A bibliometric analysis. *International Journal of Social Sciences and Education Research*, *11*(3), 163–174. https://doi.org/10.24289/ijsser.1732375

Kumar, P., Bhamu, J., Bhadu, J., & Saraswat, P. (2025). Exploring industry 4.0 technologies for sustainable development goals: a systematic literature review. In *International Journal of Production Management and Engineering* (Vol. 13, Number 1, pp. 27–44). Universidad Politecnica de Valencia. https://doi.org/10.4995/ijpme.2025.21155

Kuncoro, T., Ichwanto, M. A., & Dwiyanto, F. A. (2025). Immersive learning through virtual reality for civil engineering education. *Cakrawala Pendidikan*, *44*(1), 92–101. https://doi.org/10.21831/cp.v44i1.50351

Lorin W. Anderson, David R. Krathwohl-A taxonomy for learning teaching and assessing_ a revision of Bloom`s taxonomy of educational objetives-Longman (2001). (n.d.).

Mubarok, H., Hwang, G.-J., Lin, C.-J., & Darmawansah, D. (2023). *Implementation of collaborative project-based learning approach: Spherical video-based virtual reality creation*.

Mustaqim, I., Setyosari, P., Kamdi, W., & Ulfa, S. (2024). Building the foundation for creativity and collaboration: Knowledge sharing learning models. *Cakrawala Pendidikan*, *43*(1), 262–272. https://doi.org/10.21831/cp.v43i1.60380

Mynbayeva, A., Vishnevskay, A., & Sadvakassova, Z. (2016). Experimental Study of Developing Creativity of University Students. *Procedia - Social and Behavioral Sciences*, *217*, 407–413. https://doi.org/10.1016/j.sbspro.2016.02.113

Nurainia, N., & Apriadi, E. A. (2025). Literature Review on the Role of AI (Artificial Intelligence) in Industry 4.0 Transformation. *International Journal of Technology and Computer Science*, *1*(1), 25–37. https://doi.org/10.58290/ijtcs.v1i1.123

Ontiveros, Y. O., González, J. R., & Palencia, J. L. D. (2025). Integrating creative thinking and cultural insights through the anthropological theory of didactics in university algebra. *Journal of Education and Learning*, *19*(2), 742–750. https://doi.org/10.11591/edulearn.v19i2.21461

Panjaitan, M. B., & Siagian, A. (2020). The effectiveness of inquiry based learning model to improve science process skills and scientific creativity of junior high school students. *Journal of Education and E-Learning Research*, *7*(4), 380–386. https://doi.org/10.20448/journal.509.2020.74.380.386

Panjaitan, M. B., Siagian, A. F., Purba, N., Herman, H., Sutikno, S., Sinaga, Y. K., & Sihombing, S. D. (2025). Fostering the Use of Talking Stick Learning Model on the Critical Thinking Ability in Science Learning. *Journal of Curriculum and Teaching*, *14*(4), 14–25. https://doi.org/10.5430/jct.v14n4p14

Putri, M. E., Ahda, Y., Anhar, A., & Putri, D. H. (2023). Effect of Problem-Based Learning Models and Prior Knowledge toward Critical Thinking Skills on Human Digestive and Circulatory System. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 3905–3914. https://doi.org/10.29303/jppipa.v9i5.3697

Rahardhian, A. (2022). Kajian Kemampuan Berpikir Kritis (Critical Thinking Skill) dari Sudut Pandang Filsafat. *Jurnal Filsafat Indonesia*, *5*.

Rea, S. C. E., Maasawet, E. T., Hudiyono, Y., Raharjo, B., Palenewen, E., & Tindangen, M. (2024). Improving Critical and Creative Thinking Skills with Articulate Storyline Media in Learning Food and the Human Digestive System in Grade XI. *Jurnal Penelitian Pendidikan IPA*, *10*(11), 8899–8910. https://doi.org/10.29303/jppipa.v10i11.9127

Reyes Domínguez, D., Infante Abreu, M. B., & Parv, A. L. (2024). Main Trend Topics on Industry 4.0 in the Manufacturing Sector: A Bibliometric Review. *Applied Sciences (Switzerland)*, *14*(15). https://doi.org/10.3390/app14156450

Rizki, A., Khaldun, I., & Pada, A. U. T. (2021). Development of Discovery Learning Student Worksheets to Improve Students' Critical Thinking Skills in Chemical Balance Materials. *Jurnal Penelitian Pendidikan IPA*, *7*(4), 707–711. https://doi.org/10.29303/jppipa.v7i4.829

Rukmana, H., & Salirawati, D. (2024). Influence of Mobile Learning Based on Articulatde Storyline 3 on Colloid Materials on Students' Learning Interest. *Jurnal Penelitian Pendidikan IPA*, *10*(2), 731–737. https://doi.org/10.29303/jppipa.v10i2.5639

Sah, B. P., Tanha, N. I., Sikder, M. A., & Habibullah, S. M. (2024). The Integration Of Industry 4.0 And Lean Technologies In Manufacturing Industries: A Systematic Literature Review. *Global Mainstream Journal*, *1*(3), 14–25. https://doi.org/10.62304/ijmisds.v1i3.164

Salhuteru, C. P., Papilaya, P. M., & Muskita, M. (2025a). Integrated PjBL-STEAM Jigsaw on Critical Thinking and Creative Thinking of Students: A Biotechnology Study. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 910–922. https://doi.org/10.29303/jppipa.v11i1.9632

Salhuteru, C. P., Papilaya, P. M., & Muskita, M. (2025b). Integrated PjBL-STEAM Jigsaw on Critical Thinking and Creative Thinking of Students: A Biotechnology Study. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 910–922. https://doi.org/10.29303/jppipa.v11i1.9632

Saralee, A., Fitria, Y., Sukma, E., & Hidayati, A. (2024). the Development of E-Module IPAS Based on Problem Based Learning Assisted with Articulate Applications to Improve Students Think Critically. *Jurnal Penelitian Pendidikan IPA*, *10*(4), 2032–2040. https://doi.org/10.29303/jppipa.v10i4.7014

Siagian, A. F., Ibrahim, M., & Supardi, Z. A. I. (2022). The Effectiveness of the Creative-Scientific Decision Making Skills (CSDMS) Model to Practice Creative Thinking Skills and Decision Making Skills. *IJORER : International Journal of Recent Educational Research*, *3*(5), 631–639. https://doi.org/10.46245/ijorer.v3i5.251

Siagian, A. F., Ibrahim, M., & Supardi, Z. A. I. (2023). Creative-scientific decision-making skills learning model for training creative thinking skills and student decision making skills. *Nurture*, *17*(1), 10–17. https://doi.org/10.55951/nurture.v17i1.141

Siagian, G., Lufri, L., Razak, A., Festiyed, F., Diliarosta, S., Simanjuntak, H., & Siagian, F. (n.d.). Implementation of Problem Based Learning (PBL) Model Based on Local Wisdom of Dalihan Natolu Used by Animation Video to Improve Students' Creative Thinking Skills 1536 Evolutionary Studies in Imaginative Culture. In *ESIC2024* (Vol. 8).

Syahfitri, J., & Muntahanah. (2024). The effectiveness of local wisdom-based interactive digital module on students' critical thinking disposition. *International Journal of Evaluation and Research in Education*, *13*(4), 2171–2178. https://doi.org/10.11591/ijere.v13i4.28256

Syarifatul luthfia. (2024). Enhancement of Creative Thinking Skill Using Creative Problem Solving Learning Model. *International Journal of Education and Teaching Zone*, *3*(1), 107–118. https://doi.org/10.57092/ijetz.v3i1.197

Tamrin, A. G., Triyono, M. B., Saputro, I. N., Sucipto, T. L. A., & Asnur, L. (2025). Enhancing creative teaching behavior of vocational school teachers: structural equation modeling analysis. *Journal of Education and Learning*, *19*(1), 221–231. https://doi.org/10.11591/edulearn.v19i1.21812

Trianggono, M. M. (2017). *Analisis Kausalitas Pemahaman Konsep Dengan Kemampuan Berpikir Kreatif Siswa Pada Pemecahan Masalah Fisika*. http://e-journal.unipma.ac.id/index.php/JPFK

Usman, A., Eurika, N., Priantari, I., Awalludin, A. R., & Hilia, G. M. (2023). Improving Studentsâ€™ Creative Thinking Skills by Combining Cooperative Script and Reciprocal Teaching Models. *Journal of Innovation in Educational and Cultural Research*, *4*(3), 391–398. https://doi.org/10.46843/jiecr.v4i3.684

Wahyuni, S., Gusti Made Sanjaya, I., Erman, & Jatmiko, B. (2019). Edmodo-based blended learning model as an alternative of science learning to motivate and improve junior high school students' scientific critical thinking skills. *International Journal of Emerging Technologies in Learning*, *14*(7), 98–110. https://doi.org/10.3991/ijet.v14i07.9980

Wibowo, A. M., Utaya, S., Wahjoedi, W., Zubaidah, S., Amin, S., & Prasad, R. R. (2024). Critical Thinking And Collaboration Skills On Environmental Awareness In Project-Based Science Learning. *Jurnal Pendidikan IPA Indonesia*, *13*(1), 103–115. https://doi.org/10.15294/jpii.v13i1.48561

Widiana, W., & Jampel, N. (2016). Improving Students' Creative Thinking and Achievement through The Implementation of Multiple Intelligence Approach with Mind Mapping. *International Journal of Evaluation and Research in Education (IJERE)*, *5*(3), 246–254.

Yildiz, C., & Guler Yildiz, T. (2021). Exploring the relationship between creative thinking and scientific process skills of preschool children. *Thinking Skills and Creativity*, *39*. https://doi.org/10.1016/j.tsc.2021.100795