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Enhancement of Indonesian Junior High School Student Creative Thinking Skills Through a STEM-Project Based Learning: A Case Study of Quasi-Experimental Evidence

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ABSTRACT

The main vision of education, especially in learning natural sciences must be able to develop student creative thinking skills. Creative thinking has a position that is as important as understanding concepts, so this encourages researchers to look for learning processes and learning environments that are able to encourage students to creative thinking. The purpose of this study is to analyze the effect Project Based Learning through a science, technology, engineering and math (STEM) education approach on creative thinking skills. This research was a case study of quasi-experimental with a nonrandomized control-group pretest-posttest design. Research samples were 109 Indonesian junior high school student, which comprises one experiment class group and one control class group determined by a cluster random sampling technique. The data collection instrument was in the form of creative thinking skills essay questions. The research data were analyzed using Quade's Rank Analysis of Covariance because the research data did not meet the normality test requirements. The results of the study show that class using STEM-PjBL learning are significantly better at creative thinking skills when compared to class using Problem-Based Learning model. This research contributes to providing innovative alternative learning information in order to empower junior high school students' creative thinking skills.

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1. INTRODUCTION

The 21st century is marked by the development of science (Sahoo, 2021) and information (Bohalo, 2020). This development has an impact on various aspect of economic life, transportation, technology and information (Redhana, 2019). This era requires various skills to be able to face life's challenge (Hashim & Hameed, 2012; Maloy, Verock, Edward, & Woolf, 2016; Nasir, 2017). An important skill for student to develop is higher order thinking skills (Gupta & Mishra, 2021; Khaeruddin et al., 2023). High order thinking is a person's skills in dealing with various global problem (Muhibbuddin, Artika, & Nurmaliah, 2023). Higher order thinking skills that student need to have include critical thinking, problem solve, creative thinking, as well as collaboration and communication (Abualrob, 2019; Barko & Sadler, 2013; Greiff et al., 2013; Sunwook et al., 2017).

One of the 21st century skills that is important to develop in student is creative thinking skills (Anam, Mudakir, & Prihatin, 2023; Usman et al., 2023). Problem solving in learning science require the ability to creative thinking, because problem solving is not only focused on understanding the problem but also developing various student solution idea in the process of getting the essence of a problem (Akben, 2020; Allen & Gerras, 2009; Erdem & Adiguzel, 2019). Creative thinking is also important in the student learning process to help problem solving, generate ideas as new views and be able to argue in response to problem faced (Chang, Hung, & Lin, 2014; Wiggins, 2018). When a student has good creative thinking skills they tend to be able to spark ideas, produce innovative solution and draw conclusion in the learning process (Carlson, 2023; Purwati & Alberida, 2022). The basic characteristic of creative thinking is showing the efficiency of mental activity and student ability to face problem and be responsible (Erdem & Adiguzel, 2019; Gajda, Karwowski, & Beghetto, 2016; Karwowski & Gralewski, 2012). Based on the Global Creativity Index data in terms of technology, talent, and tolerance,

Indonesia's country ranking is located at 115 out of a total of 139 countries (Gifari & Madhakomala, 2023). The data shows that in Indonesia, creative thinking is still in the low category.

Several previous researchers also explained that there was still a lack of student creative thinking skills and there were problems encountered in effort to develop student creative thinking skills (Cheng, 2010; Gomez, 2007; Laius & Rannikmäe, 2014; Suratno et al., 2019). Creative thinking is a skill that is needed in a classroom environment and can be developed through certain learning approach (Gomez, 2007; Okpara, 2007). Referring to the development of education in terms of developed countries which are currently being intensified namely learning that involves multi-disciplinary knowledge (Kara, 2018; Neill et al., 2019; Sokolowski, 2018), one of which is the approach of science, technology, engineering, and math (STEM) (Kong & Matore, 2022). STEM education proposes the interdisciplinary integration of knowledge, skills and belief related to more than one STEM discipline through the collaborative effort of student and teacher (Corlu, Sencer, & Capraro, 2014; Oner et al., 2014). The four aspect of STEM are needed simultaneously to create an active and cohesive learning system to solve a problem (Smith et al., 2022; Wakhid & Nadhiroh, 2021; Zhan & Niu, 2023). STEM education is felt to be important for the future of the nation and the future of the younger generation to shape everyday experience and therefore it is necessary to pay attention to the implementation of STEM teaching in school to prepare students for global competitiveness (Birenbaum et al., 2006; Lavi, Tal, & Dori, 2021; Malti, 2017).

STEM is becoming a hot and important learning approach in today's world (Kelley & Knowles, 2016; Kiray & Shelley, 2018; Setiono & Windyariani, 2023). The smoothness of the science learning process cannot be separated from the use of learning model in it. Through the application of the STEM approach student are expected to be able to find solution to complex problems and 21st century life skills in order to compete globally (Breiner, Johnson, Harkness, & Koehler, 2012; Moore, 2007; Wahono & Chang, 2019). The application of the STEM approach is usually followed by problem based learning (Nessa, Hartono, & Hiltrimartin, 2017; Sayary, Forawi, & Mansour, 2015). According Wahono, Lin, & Chang (2020), to implement STEM in the classroom and in order to get good results another learning model is needed. One example is combined with the Project-Based Learning model (Bunyamin & Finley, 2016; Chang et al., 2014; Redkar, 2012). Project-Based Learning can be one of the current learning solution that encourage student to construct their knowledge through a process of observation, experimentation and experience in working on project that are in accordance with constructivism theory (Markula & Aksela, 2022; Wahbeh et al., 2021). STEM-PjBL learning is beneficial for 21st century learning because it helps student problem solving, creative thinking, support future career (Tseng, Chang, Lou, & Chen, 2013), as well as mastering complete knowledge in science, technology, engineering, and math at the same time (English & King, 2015; Erdogan, Navruz, Younes, & Capraro, 2016). Based on the results of research that has been conducted by previous researchers, can strengthen the author's foundation in implementing STEM-PjBL learning research in seeking active learning activities that emphasize more collaborative learning, scientific, increasing student motivation and enthusiasm for learning, so that this paper was carried out to analyze the effect of the STEM-PjBL learning model on the creative thinking skills of junior high school student.

2. RESEARCH METHOD

This research is a quasi-experiment with a nonrandomized control-group pretest-posttest design. The participants in this research were 8th grade of the SMP Negeri 1 Bengkulu Selatan in the subject of Natural Sciences, particularly the topic of biomimicry. Research samples were 109 Indonesian junior high school student, which comprises one experiment class group and one control class group determined by a cluster random sampling technique. The experimental class applies the STEM-PjBL learning model and the control class applies the Problem-Based Learning. The reason for implementing the Problem-Based Learning in the control class is based on the result of a needs analysis with the Natural Sciences teacher at the school where the study stated that this learning model is a learning model that is most often applied during the learning process in class, while the STEM-PjBL model is a new learning model and has not been implemented by teacher in research school. Problem-Based Learning itself is different from STEM-PjBL because Problem-Based Learning only emphasizes problem solving activities, questions, discussion between teacher and student that focus on multi-concept problem to gain knowledge (Sukacke et al., 2022; Zhang & Ma, 2023). The research design in this paper can be reviewed based on Table 1.

Table 1. Research Design

Class	Pretest	Treatment	Posttest
Control	X_1	Problem-Based Learning	X_2
Experiment	X_1	STEM-PjBL	X_2

Source: (Leedy & Ormrod, 2015)

This research was conducted by giving a pretest to the two research sample class. The treatment was given to the experiment class by implementing STEM-PjBL learning with the topic of biomimicry learning. Meanwhile, the control class was given Problem-Based Learning with the topic of biomimicry learning. After being given

treatment, two research sample class were given a posttest. The student were not informed beforehand about the posttest. This type of research can be implemented into many learning topics, especially in Natural Sciences subjects. The reason the author uses the topic of biomimicry in this research is that biomimicry is seen as a revolution in education by offering teachers a way to inspire students of all ages by combining life sciences, STEM, creative thinking and design. This lesson provides a brief overview of concepts, processes, inspiration from nature, which equips students to solve a problem by creating an innovative technology product inspired by nature.

Retrieval of research data was carried out by testing essay questions on creative thinking skills totaling five questions designed based on indicator: fluency, flexibility, originality, and elaboration according Treffinger, which can be seen in Table 2 and assessment rubrics of creative thinking skills in Table 3. Before being tested on student, research instrument were validated through expert lecturer and science teachers at research schools so that the instrument used were suitable for use as a whole and to reduce error in measurement.

Table 2. Creative Thinking Skills Indicator

Variable	Sub Variable	Indicator
Creative Thinking	Fluency	1. Write down lot of idea 2. Presenting answer with many alternative 3. Quickly see the strength and weaknesses of an object and situation
	Flexibility	1. Provide varios interpretation of the situation 2. Think of various answer or way to solve problem from all point of view 3. Classify things according to different division
	Originality	1. Finding a unique combination different from the other 2. Problem solve with their own idea
	Elaboration	1. Enrich and develop an idea 2. Looking for a deeper meaning to the answer or problem solving by doing detailed step

Table 3. Assessment Rubrics of Creative Thinking Skills

Aspect	Description	Scoring Guidelines	Score
Fluency	Put forward thoughts and ideas	Didn't give an answer	0
		Student are able to propose ideas but the ideas presented are not relevant to the problem	1
		Student are able to convey an idea that is relevant to the problem	2
		Student are able to convey 3 ideas that are relevant to the problem	3
		Student are able to express more than 3 ideas and thoughts that are relevant to the problem	4
Flexibility	Put forward ideas and concepts that are varied, logical, relevant and come from several different points of view	Didn't give an answer	0
		Student have not been able to describe and explain their thoughts and ideas	1
		Student are able to explain their thoughts and ideas but are not accompanied by supporting facts	2
		Student are able to describe and explain at least 3 ideas and concepts accompanied by supporting facts and reasons	3
		Student are able to describe and explain more than 3 ideas and ideas accompanied by supporting facts and reasons	4
Originality	Providing ideas that are new, unique and different and	Didn't give an answer	0
		Student are able to provide 1 solution idea that is relevant but not unique and not different	1

Aspect	Description	Scoring Guidelines	Score
	appropriate to the problems faced	Student are able to put forward 2 solution ideas that are relevant, unique and different	2
		Student are able to put forward 3 solution ideas that are relevant, unique, different and logical	3
		Student are able to put forward more than 3 solution ideas that are relevant, unique, new, different and logical	4
		Didn't give an answer	0
Elaboration	Generate ideas with specific, complete and interesting detailed information	Student are unable to provide explanations of their thoughts and ideas	1
		Student are able to provide explanations of their thoughts and ideas but are not detailed and do not make plans	2
		Student are able to explain their thoughts and ideas in detail but do not make plans	3
		Student are able to provide detailed, specific and complete explanations of their thoughts and ideas accompanied by their designs	4

The research data in this paper were analyzed using non-parametric statistics to determine differences in the creative thinking skills of student who were taught using the STEM-PjBL and Problem-Based Learning. The non-parametric analysis chosen is Quade's Rank Analysis of Covariance. Prior to testing the hypothesis, a prerequisite test was carried out which consisted of normality and homogenity test, which can be seen in Table 4. The result of the normality test with the Kolmogorov-Smirnov show that the distribution of the research data is not normally distributed and the result of the homogenity test with the Levene's Test show that the data is homogeneous.

Table 4. Prerequisite Test

	Variable	N	p	α	Decision
Normality	**A. Control Class**				
	Pretest creative thinking	56	.001	.05	Not Normal
	Posttest creative thinking	56	.021	.05	Not Normal
	B. Experiment Class				
	Pretest creative thinking	53	.007	.05	Not Normal
	Posttest creative thinking	53	.075	.05	Normal
Homogeneity	**Variable**				
	Pretest creative thinking	107	.586	.05	Homogeneous
	Posttest creative thinking	107	.127	.05	Homogeneous

3. RESULT AND DISCUSSION

STEM-PjBL is a learning that links the Project-Based Learning model in which it uses the STEM approach. STEM is a scientific discipline that is closely related to one another. Science require math as a data processing tool, while technology is an application of science itself (Ozkaya, Thurston, MacKenzie, & Ain, 2023). Learning science also require an engineering design process, namely knowledge to operate or design a procedure to problem solving (Aini & Aini, 2023). STEM-PjBL is a learning that directs student in a group to collaborate in completing a project where the project integrate science, technology, engineering, and math. In STEM-PjBL learning, the most important advantage is the creation of products to solve authentic problem. his is what distinguishes STEM-PjBL learning from other student centered pedagogy, for example Problem-Based Learning.

Table 5. The Mean of Score Creative Thinking Skills

Variable	Pretest ± Standard Deviation	Posttest ± Standard Deviation	Difference
Problem-Based Learning Model	35.44 ± 47.67	47.67 ± 16.06	12.49
STEM-PjBL Model	32.64 ± 14.66	61.03 ± 13.52	28.39

The results of the research in this paper are pretest-posttest data on the creative thinking of junior high school student. Student creative thinking in class using STEM-PjBL and Problem-Based Learning model have increased, as shown in Table 5. The increase in creative thinking skill score in the STEM-PjBL class was higher

than in the Problem-Based Learning class. The difference in pretest and posttest score in the STEM-PjBL class was 28.39, while in the Problem-Based Learning class it was 12.23. Based on the prerequisite test, it is known that the data in this study do not meet the requirements for a parametric difference test. Based on this, in this study it was decided to switch to using non-parametric statistics to find out whether there were difference in student creative thinking between class using STEM-PjBL and the Problem-Based Learning in this study. The non-parametric analysis chosen is Quade's Rank Analysis of Covariance. Table 6 present a summary of the result of hypothesis testing that there is an effect of differences in STEM-PjBL and Problem-Based Learning model as well as differences in the significance of indicator of student creative thinking based on differences in the learning treatment of the two study sample class.

Table 6. Results Quade's Rank Analysis of Covariance Creative Thinking Skills

		Sum of Squares	df	Mean Square	F	Sig.
Model (STEM-PjBL, Problem-Based Learning)	Between Groups	24377.116	1	24377.116	59.425	.000
	Within Groups	43893.104	107	410.216		
	Total	68270.220	108			
Fluency	Between Groups	27802.879	1	27802.879	43.532	.000
	Within Groups	68337.982	107	638.673		
	Total	96140.861	108			
Flexibility	Between Groups	28878.535	1	28878.535	58.599	.000
	Within Groups	52731.708	107	492.820		
	Total	81610.243	108			
Originality	Between Groups	12401.266	1	12401.266	26.591	.000
	Within Groups	49901.751	107	466.372		
	Total	62303.017	108			
Elaboration	Between Groups	595.267	1	595.267	.761	.385
	Within Groups	83689.344	107	782.143		
	Total	84284.611	108			

*) Significance at $p \leq 0.05$

Results Quade's Rank Analysis of Covariance shows that there is a significant difference in student creative thinking skills between class using the STEM-PjBL learning and the Problem-Based Learning ($p < 0.05$). Furthermore, results Quade's Rank Analysis of Covariance shows that there are significant difference in student creative thinking on indicator fluency, flexibility, and originality ($p < 0.05$), however there is no significant difference in results on indicator elaboration student between class using STEM-PjBL and Problem-Based Learning ($p > 0.05$). The findings in this research, there is an influence of STEM-PjBL learning on each indicator of creative thinking and there is a significant difference in increasing students' creative thinking through STEM-PjBL learning and Problem-Based Learning. The findings in this research also show that the data on indicators of student creative thinking in the aspect of originality experienced the most significant increase after learning using STEM-PjBL which can be seen in Figure 2. Based on the analysis in this paper as a whole, it shows that the creative thinking of student who are taught using the STEM-PjBL model is significantly higher than student who are taught using the Problem-Based Learning model.

Creative thinking skills in this study are also reviewed based on the increase in each indicator. Class that using STEM-PjBL and Problem-Based Learning experience an increase in each indicator, but both have different range of increase. This percentage range shows that the increase in the score of each indicator of creative thinking is higher in the STEM-PjBL class when compared to the Problem-Based Learning class. Based on the finding of this study as a whole it can be concluded that students' creative thinking through STEM-PjBL is better when compared to Problem-Based Learning. This shows that the learning process through STEM-PjBL has the potential to improve students' creative thinking. This is based on the fact that in STEM-PjBL learning, students are invited to carry out meaningful learning in understanding concepts. Student are invited to explore through project activities, so that students are actively involved in the learning process. Through STEM-PjBL learning, it can provide students with the opportunity to explore problems that can provide solutions, thereby increasing students' ability to think creatively. This can improve creative thinking skills which encourage students to be able to see a problem from various points of view by thinking fluently, flexibly, the result of their own thoughts or elaborated. A more detailed description can be observed in the bar chart in Figure 1 for the control class and Figure 2 for the experimental class.

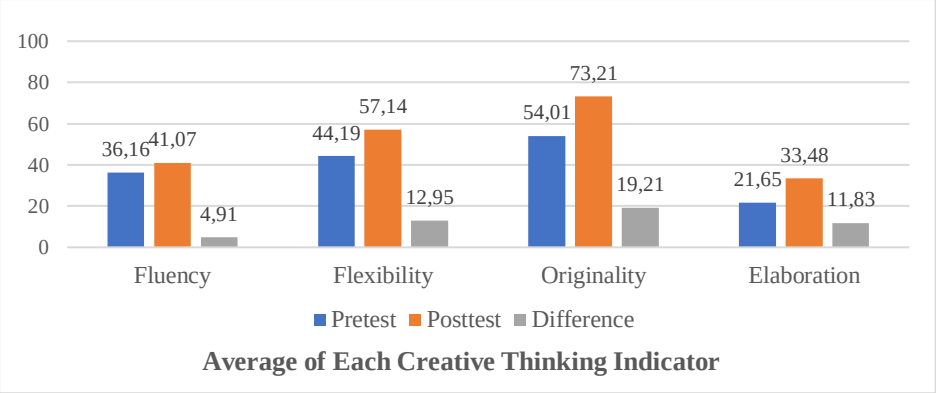

Figure 1. Diagram of the Average of Each Indicator of Creative Thinking Skills for the Control Class

The finding in this paper are in line with previous research conducted by other researchers, namely STEM-PjBL learning can improve student creative thinking skills (Lestari, Sarwi, & Sumarti, 2018; Saefullah et al., 2021). Furthermore, Shahbazloo & Mirzaie (2023) state that learning that applies the integration of science and math can increase learning achievement, greater curiosity, skills for creative thinking and increase student motivation. This is reinforced by the theoretical basis which reveal that through STEM-PjBL learning model it is possible to train student in mastering and exploring concept, problem solving and creative thinking like technician and scientist which is manifested in the form of a particular technology or product (Diana, Yohannes, & Sukma, 2021; Purwaningsih et al., 2020; Zhang & Ma, 2023), so that STEM-PjBL learning model can provide a certain opportunity for student so that in the learning process carried out they become more active, so that student can easily construct their own knowledge independently.

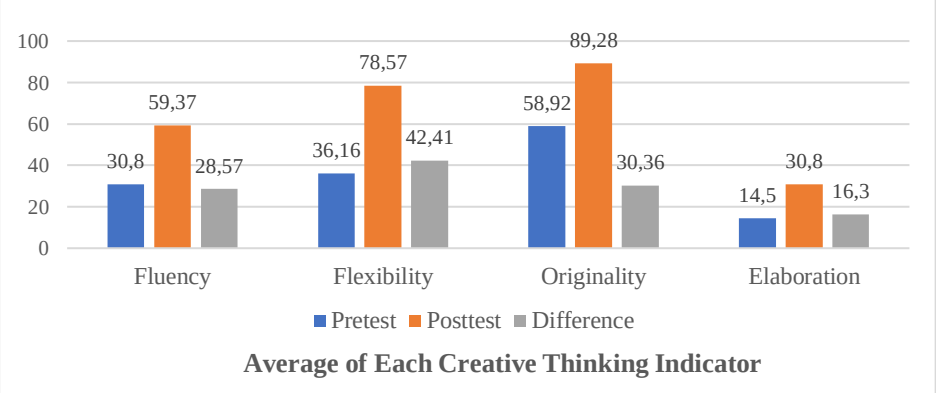

Figure 2. Diagram of the Average of Each Indicator of Creative Thinking Skills for the Experiment Class

Aspect of the STEM approach that are integrated at each stage of the learning process play a role in the success of increasing student creative thinking skills in this paper. STEM learning provide a more meaningfull and relevan learning experience STEM learning provide a more meaningfull and relevan learning experience (Mulyani, 2019; Stohlmann, Moore, & Roehrig, 2012; Syarah, Rahmi, & Darussyamsu, 2022). Science in this STEM approach includes the process of asking questions, hypothesizing, carrying out information gathering, carrying out analysis and communicating it (Lavi et al., 2021). Technology in this STEM approach is a certain process that an individual carries out with his expertise as a scientist and technician in carrying out environmental modification so that he can fulfill his desires and need (Istiana et al., 2023). Engineering in the STEM approach is a series of specific processes that include identifying problem, gathering information, developing various possible solution to problem, selecting the best problem solution, designing and executing them, conducting test, repair and assessment (Lin, Wu, Hsu, & Williams, 2021). Mathematics in this STEM approach is a pattern as well as a relationship that is used as a language in explaining the universe which includes formula, operation, number and the interrelationship of these relationship (He et al., 2021). This STEM approach basically implement how an engineer carries out his work (Hidiroglu & Karakas, 2022; Tunc & Bagceci, 2021). The learning model that exemplifies how an engineer works is Project-Based Learning model (Beuchat, Bradford, & Buskes, 2022; Hughes, Love, & Dill, 2023).

Past research has shown that using Project-Based Learning as a learning model can improve student 21st century skills as well as creative thinking skills (Issa & Khataibeh, 2021; Widarbowo et al., 2023). Project-Based Learning in this study is carried out by giving various problem to student to solve which are contextual in nature and require direct experience in forming meaning through the integration of knowledge from science, technology,

engineering and math (STEM) (Almulla, 2020). The difference between PjBL and other learning model is that in PjBL student design project and make product, so they practice doing them (Chen & Yang, 2019). The STEM-PjBL relationship in this study is an innovative learning approach, where student in PjBL are required to create project or product (Chen & Yang, 2019), while STEM is a component that has interdisciplinary relationship (Saefullah et al., 2021) which is intended to train and assist student to have 21st century life skills, which include creative thinking Based on the research finding in this paper, it is revealed that student creative thinking skill can be empowered by the STEM-PjBL learning process properly. The implementation of STEM-PjBL learning is necessary to help student be more optimal. The result of the research in this paper are expected to contributes to the academic community in seeking reference information and reference to carry out Natural Science learning, especially on the topic of biomimicry through the STEM-PjBL learning model.

The stages of the learning process that provide more support in improving students' creative thinking skills in this research are students being able to set learning goals, students discussing each other's ideas, students agreeing on solutions for solving problems in groups, students writing complete reports then carrying out presentation. At this stage, it is able to trigger ideas from different points of view and mutual respect between student and teachers. According to Wahono et al. (2021), The STEM approach can develop student ability to think and also make decisions, besides that it has a positive influence on the process of developing student thinking because it involves many perspectives. In the learning process, STEM-PjBL requires cooperation, communication between colleagues, problem solving skills and self-management. STEM-PjBL learning helps students bridge the knowledge learned at school with the real world. Integration between several fields of science in STEM-PjBL helps students provide meaning that one field of science is closely related to other fields of science.

4. CONCLUSION

These creative thinking skills are urgent and important to be empowered in the world of education. This paper concludes that the application of STEM-PjBL learning is able to improve the creative thinking of junior high school student in the subject of Natural Science, particularly the topic of biomimicry. Class that implement STEM-PjBL learning model are significantly better at student creative thinking skills when compared to class that apply Problem-Based Learning model. This is inseparable because in STEM-PjBL learning it applies project based learning that integrate the four STEM discipline in it. Based on the final result of this study, it is felt that STEM-PjBL can be utilized to support active learning activities and require student to empower student creative thinking skills.

5. REFERENCES

Abualrob, M. (2019). Determinants of building 21st century skills in palestinian elementary schools. *Higher Education Studies*, *9*(2). https://doi.org/10.5539/hes.v9n2p108

Aini, M., & Aini, M. (2023). Enhancing creative thinking and communication skills through engineering design process (EDP) learning model : A ase study. *Bioedukasi: Jurnal Biologi Dan Pembelajarannya*, *21*(1), 21–27. https://doi.org/10.19184/bioedu.v21i1.38022

Akben, N. (2020). Effects of the problem-posing approach on students' problem solving skills and metacognitive awareness in science education. *Res Sci Educ*, (50), 1143–1165.

Allen, C. D., & Gerras, S. J. (2009). Developing creative and critical thinkers. *Military Review, 89(6), 8.*, *89*(6), 8.

Almulla, M. A. (2020). The effectiveness of the project-based learning (PBL) approach as a way to engage students in learning. *Sage Journal*, 1–15. https://doi.org/10.1177/2158244020938702

Anam, M. K., Mudakir, I., & Prihatin, J. (2023). Development of hypermedia-based e-module to enhance students' creative thinking skills in the topic of digestive system for junior high school students (SMP/MTs). *Bioedukasi: Jurnal Biologi Dan Pembelajarannya*, *21*(3), 256–262. https://doi.org/10.19184/bioedu.v21i3.40941

Barko, T., & Sadler, T. (2013). Learning outcomes associated with classroom implementation of a biotechnology-themed video game. *The American Biology Teacher*, *75*(1), 29–33. https://doi.org/10.1525/abt.2013.75.1.7

Beuchat, P. N., Bradford, G. J., & Buskes, G. (2022). Challenges and opportunities of using differential-drive robots with project-based learning pedagogies. *IFAC-PapersOnLine*, *55*(17), 186–193. Retrieved from https://doi.org/10.1016/j.ifacol.2022.09.277

Birenbaum, M., Breuer, K., Cascallar, E., Dochy, F., Dori, Y., Ridgway, J., … Editor, G. N. (2006). A learning integrated assessment system. *Educational Research Review*, *1*(1), 61–67. https://doi.org/10.1016/j.edurev.2006.01.001

Bohalo, H. B. (2020). Smart Social Networking: 21st Century Teaching and Learning. *Research in Pedagogy*, *7*(1), 21–29. https://doi.org/10.17810/2015.45

Breiner, J. M., Johnson, C. C., Harkness, S. S., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *Schools Science and Mathematics*, *112*(1), 3–11.

Bunyamin, M. A. H., & Finley, F. (2016). STEM education in Malaysia: Reviewing the current physics curriculum. *International Conference of Association for Science Teacher Education*.

Carlson, M. R. (2023). *How inquiry based learning supports creative problem solving skills in elementary art education* (Bethel University). Retrieved from https://spark.bethel.edu/etd/988

Chang, J.-J., Hung, K.-P., & Lin, M.-J. (2014). Knowledge creation and new product performance: The role of creativity. *R & D Managenent*, *44*(2), 107–123.

Chen, C.-H., & Yang, Y.-C. (2019). Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. *Educational Research Review*, *26*, 71–81. https://doi.org/10.1016/j.edurev.2018.11.001

Cheng, V. M. Y. (2010). Teaching creative thinking in regular science lessons: Potentials and obstacles of three different approaches in an asian context. *Asia-Pasific Forum on Science Learning and Teaching*, *11*(1), 1–21.

Corlu, Sencer, M., & Capraro, R. M. (2014). Introducing STEM education: implications for educating our teachers for the age of innovation. *Education and Science*, *39*(171), 74–85.

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

English, L. D., & King, D. T. (2015). STEM learning through engineering design: fourth-grade students' investigations in aerospace. *International Journal of STEM Education*. https://doi.org/10.1186/s40594-015-0027-7

Erdem, A. R., & Adiguzel, D. C. (2019). The opinions of primary school teachers on their creative thinking skills. *Eurasian Journal of Educational Research*, (80), 25–38.

Erdogan, N., Navruz, B., Younes, R., & Capraro, R. M. (2016). Viewing how STEM project- based learning influences students' science achievement through the implementation lens: A latent growth modeling. *Eurasia Journal of Mathematics, Science & Technology Education*, *12*(8), 2139–2154. https://doi.org/10.12973/eurasia.2016.1294a

Gajda, A., Karwowski, M., & Beghetto, R. A. (2016). Creativity and academic achievement: A meta-analysis. *Journal of Educational Psychology*, 1–32. Retrieved from http://dx.doi.org/10.1037/edu0000133

Gifari, F., & Madhakomala, R. (2023). Education and training (diklat) -based human resource development to increasing employee creativity: Literature study. *Journal of Advances in Accounting, Economics, and Management*, *1*(2), 1–15.

Gomez, J. G. (2007). Editor's desk what do we know about creativity? *The Journal of Effective Teching*, *7*(1), 31–43. https://doi.org/10.2501/JAR-2020-005

Greiff, S., Wüstenberg, S., Fischer, A., Funke, J., Molnar, G., & Csapo, B. (2013). Complex problem solving in educational contexts - Something beyond g: Concept, assessment, measurement invariance, and construct validity. *Journal of Educational Psychology*, *105*(2), 364–379.

Gupta, T., & Mishra, L. (2021). Higher-order thinking skills in shaping the future of students. *Psychology and Education*, *58*(2), 9305–9311.

Hashim, M., & Hameed, F. (2012). Human resource management in 21st century: Issues & challenges & possible solutions to attain competitiveness. *International Journal of Academic Research in Business and Social Sciences*, *2*(9), 44–55.

He, X., Li, T., Turel, O., Kuang, Y., Zhao, H., & He, Q. (2021). The impact of STEM education on mathematical development in children aged 5-6 years. *International Journal of Educational Research*, *109*(June 2020), 101795. https://doi.org/10.1016/j.ijer.2021.101795

Hidiroglu, C. N., & Karakas, Y. (2022). Transdisciplinary role of technology in STEM education. *Malaysian Online Journal of Educational Technology*, *10*(4), 276–293.

Hughes, A. J., Love, T. S., & Dill, K. (2023). Characterizing highly effective technology and engineering educators. *Education Sciences*, *13*, 560. Retrieved from https://doi.org/ 10.3390/educsci13060560

Issa, H. B., & Khataibeh, A. (2021). The effect of using project based learning on improving the critical thinking among upper basic students from teachers' perspectives. *Pegem Journal of Education and Instruction*, *11*(2), 52–57. https://doi.org/10.14527/pegegog.2021.00

Istiana, R., Herawati, D., Herniningtyas, F., Ichsan, I. Z., & Ali, A. (2023). STEM learning to improve problem solving ability on the topic of environmental education. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1202–1208. https://doi.org/10.29303/jppipa.v9i3.2979

Kara, M. (2018). A systematic literature review: Constructivism in multidisciplinary learning environments. *International Journal of Academic Research in Education*, *4*(1–2), 19–26. https://doi.org/10.17985/ijare.520666

Karwowski, M., & Gralewski, J. (2012). Creativity and school grades: A case from Poland. *Thinking Skills and Creativity*, *7*(3), 198–208. https://doi.org/10.1016/j.tsc.2012.03.002

Kelley, T. R., & Knowles, J. G. (2016). A Conceptual framework for integrated STEM education. *International Journal of STEM Education*, *3*(1), 11. https://doi.org/10.1186/s40594-016-0046-z

Khaeruddin, K., Indarwati, S., Sukmawati, S., Hasriana, H., & Afifah, F. (2023). An analysis of students' higher order thinking skills through the project-based learning model on science subject. *Jurnal Pendidikan Fisika Indonesia*, *19*(June), 47–54. https://doi.org/10.15294/jpfi.v19i1.34259

Kiray, A., & Shelley, M. (2018). *Research highlights in stem education*. USA: ISRES Publishing.

Kong, S. F., & Matore, M. E. E. M. (2022). Can a science, technology, engineering, and mathematics (STEM) approach enhance students' mathematics performance? *Sustainability*, *14*, 379.

Laius, A., & Rannikmäe, M. (2014). Longitudinal teacher training impact on students' attributes of scientific literacy. *International Journal of Humanities and Social Science*, *4*(6), 63–72.

Lavi, R., Tal, M., & Dori, Y. J. (2021). Perceptions of STEM alumni and students on developing 21st century skills through methods of teaching and learning. *Studies in Educational Evaluation*, *70*, 101002. https://doi.org/10.1016/j.stueduc.2021.101002

Leedy, P. D., & Ormrod, J. E. (2015). *Practical research planning and design*. Pearson.

Lestari, T. P., Sarwi, & Sumarti, S. S. (2018). STEM-based project based learning model to increase science process and creative thinking skills of 5th grade. *Journal of Primary Education*, *7*(1), 18–24.

Lin, K., Wu, Y., Hsu, Y., & Williams, P. J. (2021). Effects of infusing the engineering design process into STEM project-based learning to develop preservice technology teachers' engineering design thinking. *International Journal of STEM Education*, *9*, 1–15.

Maloy, R. W., Verock, R. E. A., Edward, S. A., & Woolf, B. P. (2016). *Transforming learning with new technologies*. Pearson.

Malti. (2017). Need and importance of STEM education in indian schools. *Indian Journal of Research*, *6*(1), 852.

Markula, A., & Aksela, M. (2022). The key characteristics of project-based learning: How teachers implement projects in K-12 science education. *Disciplinary and Interdisciplinary Science Education Research*, *4*(2). Retrieved from https://doi.org/10.1186/s43031-021-00042-x

Moore, J. W. (2007). Critical needs of STEM education. *Journal of Chemical Education*, *84*(12), 2007.

Muhibbuddin, Artika, W., & Nurmaliah, C. (2023). Improving critical thinking skills through higher order thinking skills (HOTS) - based science. *International Journal of Instruction*, *16*(4), 1308–1470. https://doi.org/10.29333/iji.2023.16417a

Mulyani, T. (2019). Pendekatan pembelajaran STEM untuk menghadapi revolusi. *Seminar Nasional Pascasarjana 2019*, ISSN: 2686-6404.

Nasir, S. Z. (2017). Emerging challenges of HRM in 21st century: A theoretical analysis. *International Journal of Academic Research in Business and Social Sciences*, *7*(3), 216–223. https://doi.org/10.6007/IJARBSS/v7-i3/2727

Neill, M. O., Adams, M. P., Bandelt, M. J., Chester, S. A., Cai, W., & Nadimpalli, S. P. V. (2019). Cohort learning: Supporting transdisciplinary communication and problem-solving skills in graduate STEM researchers. *International Journal of Teaching and Learning in Higher Education*, *31*(1), 166–175.

Nessa, W., Hartono, Y., & Hiltrimartin, C. (2017). Pengembangan buku siswa materi jarak pada ruang dimensi tiga berbasis science, technology, engineering, and mathematics (STEM) Problem-Based Learning Di Kelas X. *Jurnal Elemen*, *3*(1), 1–14.

Okpara, F. O. (2007). The value of creativity and innovation in entrepreneurship. *Journal of Asia Entrepreneurship And Sustainability*, *III*(2).

Oner, A. T., Navruz, B., Bicer, A., Peterson, C. A., Caprarao, R. M., & Caprarao, M. M. (2014). T-STEM academies' academic performance examination by education service centers: A longitudinal study. *Turkish Journal of Education*, *3*(4), 40–51.

Ozkaya, C., Thurston, A., MacKenzie, A., & Ain, Q. u. (2023). What works for high attaining girls in primary schools in math, science and STEM courses? *International Journal of Educational Research Open*, *5*, 100283. Retrieved from https://doi.org/10.1016/j.ijedro.2023.100283

Purwaningsih, E., Sari, S. P., Sari, A. M., & Suryadi, A. (2020). The effect of STEM-PjBL and discovery learning on improving students' problem-solving skills of the impulse and momentum topic. *Jurnal Pendidikan IPA Indonesia*, *9*(4), 465–476. https://doi.org/10.15294/jpii.v9i4.26432

Purwati, S., & Alberida, H. (2022). Profile of students' creative thinking skills in high school. *Thinking Skills and Creativity Journal*, *5*(1), 22–27.

Redhana, I. W. (2019). Mengembangkan keterampilan abad ke-21 dalam pembelajaran kimia. *Jurnal Inovasi Pendidikan Kimia*, *13*(1), 2239–2253.

Redkar, S. (2012). Teaching advanced vehicle dynamics using a project based learning (PBL) approach. *Journal of STEM Education*, *13*(3), 17–28.

Saefullah, A., Suherman, A., Utami, R. T., Antarnusa, G., Rostikawati, D. A., & Zidny, R. (2021). Implementation of PjBL-STEM to improve students' creative thinking skills on static fluid topic. *Jurnal Ilmu Pendidikan Fisika*, *6*(2), 149–157. https://doi.org/10.26737/jipf.v6i2.1805

Sahoo, P. R. (2021). Reimagining the role of science education in development of 21st century learning skills with reference to NEP 2020. *Educational Quest: An Int. J. of Education and Applied Social Sciences*, *12*(2),

161–168. https://doi.org/10.30954/2230-7311.2.2021.14

Sayary, A., Forawi, S., & Mansour, N. (2015). STEM education and problem-based learning. *The Routledge International Handbook of Research on Teaching Thinking*, 357–369.

Setiono, S., & Windyariani, S. (2023). Development of online STEM learning program for the preparation of prospective 21 st century biology teacher. *Biioedukasi: Jurnal Biologi Dan Pembelajarannya*, *21*(3), 181–188. https://doi.org/10.19184/bioedu.v21i3.40383

Shahbazloo, F., & Mirzaie, R. A. (2023). Investigating the effect of 5E-based STEM education in solar energy context on creativity and academic achievement of female junior high school students. *Thinking Skills and Creativity*, *49*, 101336. Retrieved from https://doi.org/10.1016/j.tsc.2023.101336

Smith, K., Maynard, N., Berry, A., Stephenson, T., Spiteri, T., Corrigan, D., … Smith, T. (2022). education sciences principles of problem-based earning (PBL) in STEM education: Using expert wisdom and research to frame educational practice. *Education Sciences*, *12*, 728.

Sokolowski, A. (2018). *Scientic inquiry in mathematics - theory and practice*. https://doi.org/10.1007/978-3-319-89524-6

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER)*, *2*(1), 28–34. https://doi.org/10.5703/1288284314653

Sukacke, V., Guerra, A. O. P. d C., Ellinger, D., Carlos, V., Petroniene, S., Gaiziuniene, L., … Brose, A. (2022). Towards active evidence-based learning in engineering Education: A systematic literature review of PBL, PjBL, and CBL. *Sustainability*, *14*, 13955. Retrieved from https://doi.org/ 10.3390/su142113955%0AAcademic

Sunwook, H., Namjun, K., Jeongsuk, S., Wonhee, S., Kapjung, L., Seongja, C., & Kyounghoon, L. (2017). Development and effectiveness of STEAM outreach program based on mathematics. *Communications of Mathematical Education*, *31*(4), 389–407.

Suratno, Komaria, N., Yushardi, Dafik, & Wicaksono, I. (2019). The effect of using synectics model on creative thinking and metacognition skills of junior high school students. *International Journal of Instruction*, *12*(3), 133–150.

Syarah, M. M., Rahmi, Y. L., & Darussyamsu, R. (2022). Analisis penerapan pendekatan STEM pada pembelajaran. *BIO-EDU: Jurnal Pendidikan Biologi*, *6*(3), 236–243. https://doi.org/10.32938/jbe.v6i3.1260

Tseng, K.-H., Chang, C.-C., Lou, S.-J., & Chen, W.-P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. *International Journal Technology and Design Education*, *23*(162), 87–102. https://doi.org/10.1007/s10798-011-9160-x

Tunc, C., & Bagceci, B. (2021). Teachers' views of the implementation of STEM approach in secondary schools and the effects on students. *Pedagogical Research*, *6*(1), 1–11.

Usman, A., Eurika, N., Priantari, I., Awalludin, A. R., & Hilia, G. M. (2023). Improving students' 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

Wahbeh, D. G., Najjar, E. A., Sartawi, A. F., Abuzant, M., & Daher, W. (2021). The role of project-based language learning in developing students' life skills. *Sustainability*, *13*, 1–14.

Wahono, B., & Chang, C.-Y. (2019). Assesing teacher's attitude, knowledge, and application (AKA) on STEM: An effort to foster the sustainable develpment of STEM education. *Sustainability*, *11*, 950. https://doi.org/10.3390/su11040950

Wahono, B., Lin, P.-L., & Chang, C.-Y. (2020). Evidence of STEM enactment effectiveness in asian student

learning outcomes. *International Journal of STEM Education*, *1*, 1–18.

Wahono, B., Narulita, E., Chang, C., Darmawan, E., & Irwanto, I. (2021). The role of students' worldview on decision-making: An Indonesian case study by a socio-scientific issue-based instruction through integrated STEM education. *Eurasia Journal of Mathematics, Science & Technology Education*, *17*(11).

Wakhid, M. U., & Nadhiroh, N. (2021). Analysis of the potential use of STEM approach in biology lessons refers to development of science in Indonesia. *AdvaNces in Social Sciences, Education and Humanities Research*, *541*(Isse 2020), 123–131.

Widarbowo, D., Nofirman, Jasiah, Surur, M., & Astuti, E. D. (2023). Meta-analysis study for the use of project based learning models in teaching and learning activities. *Journal on Education*, *05*(04), 16306–16311.

Wiggins, G. A. (2018). Creativity, information, and consciousness: The information dynamics of thinking. *Physics of Life Reviews*, 1–35. https://doi.org/10.1016/j.plrev.2018.05.001

Zhan, Z., & Niu, S. (2023). Subject integration and theme evolution of STEM education in K-12 and higher education research. *Humanities & Social Sciences Communications*, 1–13. https://doi.org/10.1057/s41599-023-02303-8

Zhang, L., & Ma, Y. (2023). A study of the impact of project-based learning on student learning effects: A meta-analysis study. *Frontiers in Psychology*, *14*(July), 1–14. https://doi.org/10.3389/fpsyg.2023.1202728