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The Impact of Digital-Based STEAM Learning on High School Students' Creative Thinking Skills : A Literature Review

Muhammad Ghiyats Naufal[1*], Dwikoranto[1], Iqbal Ainur Rizki[2]
[1]State University of Surabaya, Surabaya, Indonesia
[2]Victoria University of Wellington, Wellington, New Zealand

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ABSTRACT

Objective: *This study aims to analyze the impact of STEAM (Science, Technology, Engineering, Art, and Mathematics) learning on the creative thinking abilities of high school students. With creativity being a vital skill in the 21st century, this research addresses the gap in traditional learning methods that fail to equip students with adequate creative problem-solving skills.* ***Method:*** *The research adopts a systematic literature review (SLR) approach involving identifying, reviewing, and synthesizing 20 articles published within the last five years. Data was collected using academic databases such as Scopus, DOAJ, and Google Scholar. The selection of articles focused on those relevant to STEAM learning and creative thinking, followed by an in-depth analysis of themes and findings.* ***Results:*** *The analysis revealed that STEAM-based learning significantly enhances creative thinking skills across various indicators, including fluency, flexibility, originality, and elaboration. Integrated models like Project-Based Learning (PjBL) and Problem-Based Learning (PBL) within STEAM provide practical strategies for overcoming traditional learning challenges by offering hands-on, practical approaches. However, limitations were identified, such as the lack of research on integrating STEAM into physics education and its limited impact on students' digital literacy.* ***Novelty:*** *This study contributes to the field by highlighting the transformative potential of STEAM learning in fostering creativity, particularly when integrated with cultural and contextual elements relevant to students. It also emphasizes the importance of expanding STEAM research into less-explored areas, such as physics education and advanced digital technologies.*

INTRODUCTION

Entering the era of the Industrial Revolution 4.0 in the 21st century, almost all human activities are dominated by high-tech and sophisticated products. This explains that science and technology are developing quickly, so the impact cannot be avoided. However, with the development of technology, it must be faced with and mastered. As stated in law No. 20 of 2003 concerning the National Education system, education has the function of developing abilities and shaping the character and civilization of a dignified nation to educate the nation's life (Rohmah et al., 2022). The abilities needed and must be mastered by high school students in the 21st 21st-century school education must master various skills, including critical thinking and creative thinking, problem-solving, creativity and innovation, collaboration, communication, information literacy, flexibility, leadership and responsibility, as well as social and cross-cultural interactions, and the most important thing is to have the ability to think creatively (Fajri et al., 2020; Laar et al., 2020; Rahman et al., 2019). Thinking creatively is an important ability for a person (Pangestu et al., 2019; Wulandari et al., 2020). The aspects used to measure creative thinking ability include fluency, flexibility, originality, and elaboration (Ulinnuha et al., 2019; Rohman et al., 2021; Mashitoh et al., 2021). Creative thinking skills are critical because they can familiarize students with solving problems in various

ways that are by their thinking, creative thinking can make students have a high sense of curiosity, thus encouraging students to always think creatively in exploring and finding new ideas (Trimawati et al., 2020).

A high school student needs to have the ability to think creatively in exploring new innovative ideas, and it will also help in learning so that it will be easier to understand real problems (Nurhikmayati et al., 2020). Unfortunately, however, students' creative thinking skills are low. Analysis of the 2019 PISA (Program for International Student Assessment) study in the science performance category shows that Indonesia is ranked 70 out of 78 countries. The PISA data above states that the creative thinking skills of students are not optimal; the reality in the world of Indonesian education shows that the creative thinking skills of students are still very low, and the low creative thinking skills are believed to be because educators do not try to explore students' knowledge and understanding of creative thinking and also do not provide sufficient learning motivation (Purwadhi, 2019). Students who are not motivated to learn because it is difficult to follow the lessons delivered by educators will experience a decrease in creative thinking skills (Mesra et al., 2023).

The motivation to learn and the ability to think of students decreases due to the learning process that emphasizes the understanding of a concept, principle, and theory but does not equip students with creative thinking skills (Darling-Hammond et al., 2019; Rahmawati et al., 2019). Teachers tend not to use a variety of learning models, thus causing students to understand the teacher's explanation less, not motivated to learn, and not causing self-confidence in students. The problem of creative thinking skills of high school students in schools is also still low due to the assignment and teaching methods of teachers who are considered not varied; a learning model is needed by using the current model (Lisnani et al., 2020; Septian et al., 2020; Utomo et al., 2020). Not only that, but the problems faced by the world of education in Indonesia regarding creative thinking are also due to the implementation of face-to-face learning in rotation after the Covid-19 pandemic, which has triggered a decrease in the ability to think creatively by students (Nurfadillah et al., 2022). Based on research conducted by (Mulyadi et al., 2022). the implementation of limited face-to-face learning causes learning limitations so that the application of learning is ambiguous, and the understanding received by students decreases. During teaching and learning activities, the problems given to students are problems that only have one way of solving. As a result, they tend to memorize problem solutions according to the solution steps; this can cause the creative thinking ability of high school students to decrease. Efforts that should be made are through STEAM learning to invite them to think creatively actively when learning in class (Puspaningtyas, 2019).

One of the efforts that can be made to solve some of the problems above, namely with practical and innovative learning in improving creative thinking skills, is to produce a generation of nations that are by the demands of the 21st century. One learning pattern that can be applied is the application of STEAM learning (Science, Technology, Engineering, Art, and Mathematics) (Dywan et al., 2020). The STEAM approach is a multi-discipline that develops from the STEM approach by adding elements of Art to its learning (Mu'minah et al., 2020). Art elements that can be explored, such as aesthetics, ergonomics, sociology and psychology, and even education; the importance of art elements considering life goes hand in hand with the development of culture, which is the implementation of Art (Razi et al., 2022). Learning with the STEAM approach involves learners actively, involves practical activities and is

directed at real situations. In addition, STEAM learning can direct students to develop creative thinking skills and abilities, the ability to solve problems, and easily collaborate (Mufida et al., 2020). However, STEAM has weaknesses; one of the problems in implementing STEAM is the lack of STEAM-based learning models and tools. Aprilia (2022), states that few educators are still confused about how to apply STEAM in learning. The STEAM learning model will be readily understood from STEAM learning videos, not just theory. Sari (2020) provides STEAM-based realistic learning but not STEAM-in learning; videos are a means of visualization. According to Darmadi (2021), for visualization, it is important to make videos. STEAM learning can support and improve student achievement (Ambarsari et al., 2019).

This research aims to determine the effect of STEAM learning on the creative thinking skills of high school students. The results of the literature review are expected to help improve the quality of education in Indonesia by creating engaging, innovative learning that has great potential to empower students' creative thinking skills, especially at the high school level. Therefore, this research was conducted to analyze how STEAM learning affects the creative thinking skills of high school students.

RESEARCH METHOD

This research was carried out using a Systematic Literature Review (SLR) by identifying, reviewing, evaluating, and interpreting available and existing research data that meet specific criteria (Simanjuntak, 2021). Data collection techniques are carried out by searching and reading several articles and journals related to the title through Mendeley, Scopus, DOAJ, and Google Scholar. A literature review contains reviews, summaries, the author's thoughts and ideas, and some supporting literature (articles, books, information from the internet, etc.) on the topic to be discussed.

This research was conducted from March to May 2024. The keywords used in this article are STEAM and Creative Thinking. The stages carried out include searching, filtering, and synthesizing the contents of articles and journals. In the search, 30 articles were obtained and filtered so that 20 were obtained for this study. The overall screening of articles was carried out based on the suitability of topics and themes with the content of the article and the publication year of at least the last 5 years. The concept map for the flow of research stages is approximate, as shown in Figure 1.

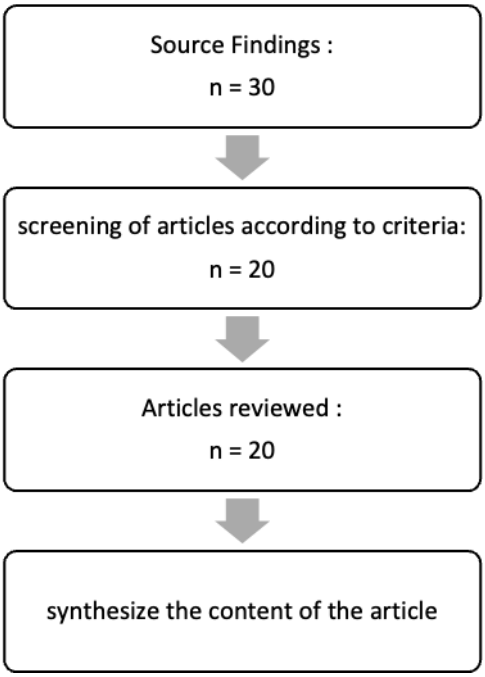

Figure 1. Research stages

RESULTS AND DISCUSSION

Results

From several articles obtained in the last 5 years or the period between 2019 and 2024, the current topic of STEAM learning on the creative thinking skills of high school students is in Table 1.

Table 1. Review results

No	Title	Author/year	Research result
1	The effectiveness of STEAM-based blended learning on students' critical and creative thinking skills	Agnesi Sekarsari Putri et al., 2023	Team-based blended learning can improve critical and creative thinking skills in all indicators with moderate to high categories.
2	Development of Personalized Physics Teaching Tools Desk Laboratory System to Enhance Creativity Thinking Ability and Scientific Attitude of Students	Hari Sri Wahyuni dan Dadan Rosana, 2019	Physics Teaching Aids Based on PDL (Personal Desk Laboratory) System to improve students' creative thinking skills and scientific attitudes is very good. valid, practical, and effective to be used to improve students' knowledge competence.
3	Exploration of continuous learning intention in STEAM education through attitude, motivation, and cognitive load.	Chih-Hung Wu, Chih-Hsing Liu dan Yueh-Min Huang, 2022	The findings of this study reveal that important factors influence students' attitudes and learning intentions about STEAM education. The theoretical and educational implications of these findings

No	Title	Author/year	Research result
			are proposed for the future of good.
4	Development and Effectiveness of STEAM-C Integrated Learning: A Tool to Enhance Students' Creative Thinking Skills in a Specific Cultural Context	Davi Apriandi, Ika Krisdiana, Edy Suprapto and Bima Adi Megantara, 2023	The results showed that the degree of validity of learning devices was in the good category, STEAM-C integrated learning devices were recommended for use in learning.
5	Creative Thinking in Art and Design Education: A Systematic Review	Mariela Samaniego et al., 2024	Its contribution to more effective pedagogical practices for the development of creative thinking that positively impacts education and prepares individuals for the challenges of the 21st century.
6	Developing critical and creative thinking skills through STEAM integration in chemistry learning	Y Rahmawati, A Ridwan, T Hadinugrahaningsih dan Soeprijanto, 2024	Students develop creativity and critical thinking skills. This study faced the challenges of STEAM integration with chemistry concepts, teacher empowerment, student engagement, and time and resource management.
7	Bachelor of Thai science, technology, engineering, arts, and math creative thinking and innovation skills (STEAM) development: Conceptual model using digital virtual. Classroom learning environment	Naphong Wannapiroon dan Paitoon Pimdee, 2022	Significant and global support was found for the research investigation and conceptual model of how VCLEs influence students' creative thinking, critical thinking skills, and innovation from STEAM education.
8	Effects of association intervention on students' creativity thinking, aptitude, empathy and design schemes in STEAM course: Considering long- and short-distance relationships	Zehui Zhan, Xiao Yao dan Tingting Li, 2023	Both distant and close association are effective strategies in enhancing creativity in STEAM courses. However, students in the distant association group achieved significantly higher levels of creative thinking.
9	STEAM and Environment on students' creative	Emma Sugandaal et al., 2021	STEAM learning can improve students' creative thinking skills. STEAM can be

No	Title	Author/year	Research result
	thinking skills: A meta-analysis study		integrated with environmental concepts. However, research on STEAM and creative thinking skills has not been done much in the field of physics.
10	Evaluation of Learning Disabled STEAM Education Student Outcomes and Creativity under UN Sustainable Development Goals: STEAM Oriented Project Based Learning Curriculum with Micro:bit	Shih-Yun Lu, Chu-Lung Wu, dan You-Ming Huang, 2022	PBL-oriented STEAM curriculum under SDG4 targets provided students with disabilities with creativity competencies and positive learning outcomes in this case study.
11	Critical Thinking Skills Of Chemistry Students By Integrating Design Thinking With Steam-Pjbl	Lintang Rizkyta Ananda, Yuli Rahmawati, Fauzan Khairi, 2023	This study reveals how the integration of Design Thinking with STEAM-PjBL can improve students' ability to think critically and creatively, in learning chemistry related to problems in everyday life.
12	Effect Of Project Based Learning (Pjbl) On Mathematical Creative Thinking Ability And Affective Mathematics Engagement	Sri Rahayuningsih, Nurasrawati, Rahmat Kamaruddin, 2022	There is an effect of PjBL application on Affective Mathematics Engagement (AME) of students. This is known from the average value of Affective Mathematics Engagement (AME) of students where in the class that applied PjBL was in the good category while in the class that applied conventional learning was in the sufficient category.
13	Integrating STEAM with PjBL and PBL in biology education: Improving Students' cognitive learning outcomes, creative thinking, and digital literacy	Wisye Hehakaya, Muhammad Nur Matdoan, Dominggus Rumahlatu, 2022	The integration of STEAM with PjBL and PBL learning models provides innovation in the application of both learning models, thereby improving learning steps and the learning process.
14	The Effect of STEAM Learning on Improving Each Indicator of	Tasta Witdiya, Gito Supriadi, Atin Supriatin, dan	Based on improvements in each indicator and regression test results on each indicator,

No	Title	Author/year	Research result
	Students' Ability to Think Creatively in Physics Learning	Jhelang Annovasho, 2023	it shows that STEAM learning has a very good effect on students' creative thinking skills. STEAM-based learning is recommended to be used as a physics learning innovation in schools to develop creative thinking to develop creative thinking.
15	The Effect Of Steam Integrated Pbl Model On Creative Thinking Skills In Terms Of Students' Concept Understanding	Agus Budiyono, Hotimatul Husna, Arin Wildani, 2020	The learning process that uses the STEAM approach will have a positive impact on fostering student creativity. The results of this study are in line with previous research that shows STEAM-based learning can train students' abilities to face the 21st century, one of which is creativity.
16	STEAM-Based Electronic Development Worksheet Improving Students' Creative Thinking Ability	Deden Dicky Dermawan , Kinanti Andartiani, 2022	The research conclusion is that the development of STEAM-based E-LKPD is suitable for distance learning activities and can improve students' creative thinking skills.
17	Development of STEAM-PjBL Based E-Worksheet in Material Reaction Rate to Improve Creative Thinking Skills of High School Students	Rp. Tasya Noor Nabila, Agus Kamaludin, 2023	Based on the assessment results, the developed E-Worksheet can be used as an alternative learning media to improve students' creative thinking skills.
18	Ensuring Youth Safety Online: The Potential Of Digital Art And Steam Education	V. Prezhdarova, D. Pastarmadzhieva, 2020	Digital art and STEAM education can provide young people with knowledge of how technology is created and then express themselves through art, which leads us to conclude that digital art can indeed support creative and critical thinking.
19	Prevalence and use of emerging technologies in STEAM education: A systematic review of the literature	Aisling Leavy, Lara Dick, Maria Meletiou, Efi Paparistodemou, Elena Stylianou,	the need for carefully designed intervention studies involving collaboration between multidisciplinary STEAM experts that use high-

No	Title	Author/year	Research result
		2023	quality measures that support the development of inferences related to learning outcomes in students' creative thinking.
20	Professional development of STEAM teaching Works: Effects on student creativity and motivation	Cathérine Conradty dan Franz Xaver Bogner, 2020	It turned out that students' self-efficacy increased. In conclusion, integrating creativity into education through PD was successful and may provide a promising channel to further proliferate science classrooms.

Discussion

The results of Sekarsari et al. (2023) showed that steam-based blended learning improved critical and creative thinking skills in all indicators with moderate to high categories. However, this study still has limitations in that the respondents only came from one school, so the study does not reflect the results of various schools. Different schools may give different results. Similar to the findings of Wahyuni et al. (2019), this study describes the development of physics teaching aids based on personalized table laboratory systems to improve students' creative thinking skills and scientific attitudes. Based on the results of the evaluation from the validator, it can be concluded that the Physics Teaching Aid Based on the PDL (Personal Desk Laboratory) System to improve students' creative thinking skills and scientific attitudes is very valid, practical, and effective to use to improve student's knowledge competencies. Similar to the article from research Chih-Hung et al. (2022), which reveals this research found ARCS and perceived usefulness, the effect of student learning attention is mediated by learning attitudes. Similar observations were also made regarding ARCS; that is, ARCS has a positive and significant effect on perceived usefulness and strengthens its effect on learning attitude, which reflects some important characteristics of STEAM, including cross-domain learning and hands-on practice, life application, problem-solving, and sensory learning, and applied those concepts to AI-based tasks in developing abilities, skills, and beliefs to better predict future careers.

Research of Apriandi et al. (2023), which involves linking culture in STEAM learning, found that by utilizing the culture in the student's environment, teachers can form creative and fun learning activities by connecting several mathematical concepts. The development of student creativity can be done by integrating mathematics content and culture to foster students' ability to develop cultural heritage according to the present context by using mathematical creative thinking skills. However, this research is limited because learning requires a relatively longer time than previous research in ordinary time. Future research can bring culture into the classroom by presenting it using technology-based tools. In the development of technology-based tools, such as in research of Samaniego et al. (2024), in its research state, there is an emphasis on hands-on learning, project-based learning, STEAM, and interdisciplinary approaches. These methods help develop a dynamic and participatory environment that encourages constant creative thinking, practice, and collaboration. Educational methodologies

centered on practical learning, projects, STEAM, and interdisciplinary approaches stand out for their ability to drive creative thinking.

Furthermore, research by Rahmawati et al. (2024) concluded that the STEAM approach can be integrated into chemistry learning in real-life problems in the Indonesian context. Important elements of critical and creative thinking skills have been stimulated in learning by active self-reflection and questioning, followed by defining problems, examining evidence, analyzing assumptions, and considering other interpretations. Students learn to apply their chemistry knowledge in solving problems with different ways of knowledge. In a study by Naphong et al. (2022), involving gamification-based learning in STEAM learning, it was concluded that significant and global support was found for the investigation of studies and conceptual models of how VCLEs influence Thai undergraduate students' creativity: thinking, critical thinking skills, and innovation from STEAM education or 'STEAM-faction' process. In addition, although there are also global studies on gamification, the success of gamification depends on a variety of factors, including technology (e.g., bit rate and streaming), site design, method, and use of game mechanics and game dynamics, as well as the emotional Educational and Information Technology aspects that contribute most to a delightful hedonic experience.

Research of Zehui et al. (2023) discusses how far and near associations with increased creative thinking in STEAM shows that far and near associations are effective strategies in increasing creativity in STEAM courses. However, students in distant association groups achieved significantly higher levels of creative thinking. Students in the close association group significantly outperformed those in the distant association group in terms of creativity aptitude and quality of design ideas. No significant differences were found among the three associations regarding students' empathy levels. These findings highlight the differential impact of distant and close associations for creativity development in STEAM education—research (Emma et al., 2021). According to the study results, STEAM learning is feasible to improve students' creative thinking skills. However, in physics learning, research on STEAM is still rare. There are only seven articles that discuss STEAM in physics learning. This shows that research on STEAM physics learning is rarely done, especially in improving creative thinking skills.

The article of Shih-Yun et al. (2022) discusses that a PBL-oriented STEAM curriculum benefits students with learning disabilities. The results of this study show immediate effects and retention. STEAM is an interdisciplinary curriculum that may be difficult to implement directly in courses. The design of the STEAM course in favor of participants with learning disabilities had positive outcomes. They acquire STEAM concepts that can cultivate their creativity, generate the ability to influence their future development and expand their range of problem-solving abilities with confidence. Given the findings of the data analysis of observations, reflective journals, researchers' diaries, and interviews with students, students' Critical Thinking skills were found to be developed and acquired in the three categories consisting of Information Search (Advanced Level in the aspects of Investigation Framing, Questioning, Gathering Information, and Source Evaluation); Interpretation and Creative Reasoning (Advanced Level in the aspects of Organization, and Advanced Level in Meaning Making); and Self-Reflection and Regulation (Advanced Level in the aspects of reflection, planning, and mindset) (Rizkyta et al., 2023).

In research of Rizkyta et al. (2023), Rahayuningsih et al. (2022), Hehakaya et al. (2022), Budiyono et al. (2020), Tasya et al. (2023) which discusses how PBL and PjBL-

based learning can improve creative thinking skills in STEAM learning because the results of STEAM integration with PjBL and PBL learning models influence cognitive learning outcomes and students' creative thinking skills. Integrating STEAM with PjBL and PBL learning models effectively empowers cognitive learning outcomes and students' creative thinking skills. However, integrating STEAM with PjBL and PBL learning models does not affect students' digital literacy. This is related to the low ability of students to utilize digital technology to search for information about concepts. In addition, the results of this study can be the basis for integrating STEAM with other learning models to improve the higher-order thinking skills and literacy of students in this digital era. In research of Witdiya et al. (2023) from the analysis, it is known that STEAM-based learning is related and influential and can improve each indicator of students' creative thinking skills. After PBL and PjBL-based learning, in contrast to research (Dermawan et al., 2022). which discusses the effectiveness of E-LKPD in improving students' creative thinking skills; STEAM-based E-LKPD is declared valid with validity according to material expert validators of 91.6 with a very valid category, media expert validators of 75 with a valid category, linguist validators of 85 with a very valid category. STEAM-based E-LKPD is declared effective based on the results of the N-Gain calculation, which shows that the N-Gain score of 0.61 is included in the moderately effective category.

The research conducted by Prezhdarova et al. (2020) has found that the younger generation has a significant role to play in the development and implementation of strategies for the development of future innovations for the construction of a new cultural era; critical and creative thinking are two of the most important qualities that allow them to fit into the digital reality adequately. Through STEAM education, children can simultaneously observe and recognize the way technology is being created and apply it in practice to express themselves through art. However, the current research is only a starting point for examining the correlation between STEAM education and creative and critical thinking development, which is expected to protect teenagers online. The pedagogically rich and innovative landscape of STEAM education has a systematic review describing various STEAM education pilot initiatives that utilize new technologies in design technology utilizing augmented reality, virtual and mixed reality, programming and robotics, maker spaces, and other technology applications in varying degrees of arts integration. Research reveals educators' efforts to develop disciplinary knowledge of science, technology, engineering, math, and, to a lesser extent, of the arts (Leavy et al., 2023; Conradty et al., 2020).

This research shows that STEAM (Science, Technology, Engineering, Art, and Mathematics) learning significantly improves high school students' creative thinking abilities, especially fluency, flexibility, originality, and elaboration. Through a literature review, it was found that project-based learning models, such as Project-Based Learning (PjBL) and Problem-Based Learning (PBL), which are integrated with the STEAM approach, are very effective in overcoming the weaknesses of traditional learning, which focuses too much on theory without practical application. This approach allows students to be directly involved in activities based on real practice, increasing creativity and motivating them to learn more actively. Furthermore, integrating local arts and cultural elements into STEAM learning has created relevant, engaging, and contextual learning experiences, which have the potential to build deeper connections between course material and students' daily lives. By providing clear insights and recommendations for educators regarding the implementation of STEAM learning, this

article makes an important contribution to supporting efforts to improve the quality of education in Indonesia and prepare students to face the challenges and needs of the 21st century creatively and innovatively.

CONCLUSION

Fundamental Finding: This research clearly shows that STEAM learning has a significant positive impact on the development of high school students' creative thinking abilities. This approach not only improves indicators of fluency, flexibility, originality, and elaboration but also provides real practice-based learning experiences that can overcome the limitations of overly theoretical learning. **Implication:** The implementation of STEAM combined with project-based learning models, such as PjBL and PBL, can be an innovative learning alternative to increase student creativity and strengthen connections between science, arts, and local culture. **Limitation:** This research has limitations in the scope of data used because it comes from literature studies that mostly focus on the application of STEAM in other countries and certain educational contexts. Additionally, the lack of research addressing the integration of STEAM with physics courses suggests a need for further exploration in this area. **Future Research:** Future research is recommended to explore the direct implementation of STEAM in various educational contexts, including physics learning. In addition, studies that integrate STEAM with digital technology in more depth, such as the use of virtual reality or artificial intelligence commonly called AI, are also needed to better understand its impact on student creativity in the digital era.

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***Muhammad Ghiyats Naufal (Corresponding Author)**
State University Of Surabaya,
Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur 60231
Email: muhammadnaufal.22042@mhs.unesa.ac.id

Dr. Dwikoranto, M.Pd.
State University Of Surabaya,
Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur 60231
Email: dwikoranto@unesa.ac.id

Iqbal Ainur Rizki

Faculty of Education,
Victoria University of Wellington,
Wellington, New Zealand
Email: rizkiiqba@myvuw.ac.nz