Vol 11(2) (2022): 185-193
DOI: http://dx.doi.org/10.24235/sc.educatia.v11i2.11440

SCIENTIAE EDUCATIA: JURNAL PENDIDIKAN SAINS

https://www.syekhnurjati.ac.id/jurnal/index.php/sceducatia

Critical Thinking Skills Using Science Technology Religion Engineering Arts and Mathematics (STREAM) Approach on Ecosystem Materials

Muhammad Hasymi Mujaddi*, Tri Wahyu Agustina, Sri Maryanti

Biology Education Study Program, Faculty of Tarbiyah and Teaching, UIN Sunan Gunung Djati, Indonesia

*Corresponding author: Cipadung, Cibiru, Kota Bandung, West Java 40614, Indonesia. E-mail address: mujaddimami612@gmail.com

a r t i c l e i n f o

Article history:
Received: 19 September 2022
Received in revised form: 21 October 2022
Accepted: 20 December 2022
Available online: 31 December 2022

Keywords:
Biology learning
Critical thinking skills
Ecosystem
STREAM

a b s t r a c t

One of the habits of mind developed in the 21st century is critical thinking skills. This study aims to describe the increase in students' critical thinking skills after learning using the approach of science, technology, religion, engineering, art, and mathematics (STREAM) on ecosystem materials. This research was conducted in one of the public high schools in Bandung Regency with a pre-experiment method whit one group pretest posttest design. The research sample was 35 students who were selected through purposive sampling technique. The instrument used is in the form of test questions that refer to the indicators of critical thinking skills as follows: giving simple explanations, building basic skills, concluding, providing further explanations and developing strategies and tactics. The data analysis technique used is to perform statistical tests. Based on the results of the study, the average value of the N-Gain critical thinking skills of students in classes using the STREAM approach was 67% in the medium category. The highest increase is in the indicator of setting strategy and tactics by 67% in the medium category. The lowest increase is the indicator providing a simple explanation of 49% in the medium category. The results of the study indicate that the STREAM approach can improve students' critical thinking skills.

1. Introduction

The 21st century is referred to as the age of knowledge, the century of information-based technology, knowledge-based economy, globalization, the industrial revolution 4.0, and so on. In this century, there have been rapid and significant changes in the economy, transportation, technology, communication, information, and education (Sudarisman, 2015; van Laar et al., 2020, Nupus et al., 2021). Also, in this century, the world of education faces enormous challenges. Therefore, the 21st century learning process must be able to prepare the Indonesian human generation to meet advances in information and communication technology in social life. Furthermore, with the presence of various kinds of challenges in the era of globalization that require competition, education has become the primary need of society and has become more crucial (Nazila et al., 2019; Rawung et al., 2021; Malik & Ubaidillah, 2020). In line with this, education should be able to produce human resources who have the skills to be able to compete in facing the challenges of the globalization era. Suto (2013) explained that the Assessment and Teaching of 21st Century Skills (ATC21S) has developed several skills that should be possessed by

students in facing the 21st century. This development is a combination of the definitions put forward by the Lisbon Council (European Union) and the Partnership for 21st century skills (United States). The skills include critical thinking, creativity and innovation, communication, problem solving and decision making, information literacy and ICT, collaboration, life and career, as well as individual and social responsibility.

Various efforts to prepare the 21st century generation need to be done. One of them is that it is necessary to master knowledge in various subjects including science education. In essence, science learning is for students to find out about natural facts systematically through a search process in order to obtain knowledge (Wati & Eka, 2015). One of the skills that are in accordance with the nature of science is critical thinking skills. Critical thinking is a disciplined process that is intellectually active and skilled at conceptualizing, applying, analyzing, synthesizing, and evaluating information gathered from or generated by observation, experience, reflection, reasoning, or communication, as a guide for belief and in taking an action (Adeyemi, 2012; Belecina & Ocampo Jr, 2018). Paul and Elder (2019) provide the view that critical thinking is an active and skilled process in conceptualizing, analyzing and evaluating something through observing, reasoning, and reflecting on it.

Critical thinking skills need to be developed and are one of the important skills for students, because through critical thinking skills, students can more easily understand concepts, and be sensitive to problems so they can understand and solve these problems. The learning process and training can prepare students to become thinkers who are able to solve problems and become independent thinkers. That way they can face the challenges of 21st-century life, overcome problems, make the right decisions, and be responsible (Sitti et al., 2012; Binkley et al., 2012). In addition, today's social culture tends to be rich in information and knowledge-oriented, making critical thinking skills one of the skills needed in the 21st century (Wang, et al., 2017; Alismail & McGuire, 2015; Brown, 2015; Erdogan, 2019; Pursitasari et al., 2020; Putra et al., 2018; Saputri et al., 2020). Critical thinking is related to wise and reflective thinking in making decisions, solving problems, and connecting with skills in providing good arguments to support ideas (D'Alessio et al., 2019; Asysyifa et al., 2019; Chen, 2017). Thus, critical thinking is a skill that involves cognitive-intellectual activity by considering logical and objective aspects in making decisions (Maryani, et al., 2021).

In fact, the critical thinking ability of high school students in Indonesia is still quite low. This is based on the results of a study conducted by the International Trends in International Mathematics and Science Study (TIMSS) in 2015. TIMSS measures students' abilities and skills in mathematics and science subjects. The question instrument presented has the characteristics of a high cognitive level that can measure students' critical thinking skills. The results show that students in Indonesia consistently fall at the bottom where Indonesia is ranked 45th out of 50 countries (Rahmawati & Nizam, 2018). The results of previous research indicate that students' critical thinking skills need to be improved (Fauzi, 2019; Roviati et al., 2019; Miarti et al., 2021; Yuliyani et al., 2021; Wati et al., 2021)

The dynamics of the development of 21st-century skills need to be overcome by presenting an innovation in learning. The government through its 2013 curriculum provides a solution so that education can help prepare students' skills in facing the developments of the 21st century. The current 2013 curriculum can be integrated with a particular approach such as the Science, Technology, Religion, Engineering, Arts and Mathematics (SRTEAM) approach to support the development of these skills. The STREAM approach is a learning approach that develops from the STEM and STEAM approaches (Agustina, et al., 2018). The STREAM approach as well as the STEM approach is an approach designed to develop 21st century skills that can be used in various areas of everyday life (Barcelona, 2014; Sen et al., 2018). STREAM was originally a strategy often

used by scientists, engineers and technicians to design a product that is beneficial to life (Bybee, 2013). The STREAM approach is multidisciplinary because it integrates several disciplines including science, technology, religion, engineering, arts, and mathematics (Agustina, et al., 2020; Capraro & Slough, 2013).

The STREAM approach steps refer to the STEM approach. The steps of the STEM approach according to Suwarma (2014) emphasize the engineering process consisting of four stages, namely: Thinking stage (P), Design stage (D), Create stage (B), and Test stage (U). At the thinking stage, students identify problems that occur in the surrounding environment to find solutions by exchanging ideas. At the design stage, students design a solution in the form of a product to solve the problems obtained. At the stage of making, students make a product as a solution that has been designed. In the test phase, students test the products that have been successfully made. If at the test stage students get failures or deficiencies in the products made, students can repair the product (Suwarma, 2014). The four stages emphasize the engineering process, integrated with the scientific process which includes the stages of formulating research questions, planning investigations, carrying out investigations, analyzing data, drawing conclusions and communicating (NRC, 2012; Agustina, et al., 2018; Widodo, 2021).

The STREAM approach, like STEM and STEAM, has several advantages when implemented in learning activities, including; the STREAM approach shows positive results in students' scientific knowledge, the STREAM approach teaches students to think to solve problems actively, creatively, and innovatively, the STREAM approach can bridge abstract concepts systematically into science, technology, inquiry and art, through technology students are able to create their ideas into the latest technology, the integration of art into STREAM will foster student creativity in creating fun learning tools, the integration of religious values (religion) in STREAM can increase students' faith and build the nation's morals, with the STREAM approach students can apply the learning outcomes obtained in everyday life (Agustina, et al., 2020; Hadinugrahaningsih et al., 2017; Syukri, 2013). In addition to having advantages, the STREAM approach has several weaknesses or shortcomings, including: requires habituation in time management, students who have weaknesses in experimenting and gathering information will have difficulty, requires mature teacher competence to prepare for the learning process (Agustina et al., 2020; Hadinugrahaningsih et al., 2017).

Ecosystem is one of the topics contained in biology subjects. In the 2013 curriculum, there are basic competencies for ecosystem materials. The basic competencies are analyzing ecosystem components and interactions between ecosystem components. Fried and Hademenos (2006) suggest that an ecosystem is a group that includes components that interact with each other at a certain place and time. The place or area is known as a habitat whose area can be as small as a fish pond or very wide like an ocean. The interactions that occur in an ecosystem involve various components, both biotic and abiotic. In the interactions that occur, there is reciprocity between these components so that they form a certain pattern. This study aims to describe the improvement of students' critical thinking skills on ecosystem materials through the STREAM approach.

2. Method

The method used in this study is the pre-experimental method, namely research conducted in the experimental group without a control class. The design used is one group pretest-posttest (Creswell, 2016). The target population is class X MIPA students from a high school in Bandung Regency for the 2021/2022 academic year, totaling 249 people. Sampling was done purposive sampling technique. The samples in this study were 35 students in class X MIPA 5 from a high school in Bandung Regency.

Data collection techniques were obtained through tests using limited description questions of 10 questions. The test instrument is used to determine the improvement and differences in students' critical thinking skills obtained from the results of the pretest and posttest scores. The indicators of critical thinking skills measured in this study use indicators of critical thinking skills according to Ennis (1985), namely: elementary clarification, basic support, inference, advanced clarification, and strategy and tactics. After obtaining the data in the form of pretest and posttest scores, an analysis was performed by comparing the pretest scores and posttest scores (gain) and conducting statistical tests. Furthermore, the results of the n-gain score are interpreted based on the n-gain criteria according to Hake (1998), namely if $n > 0.7$ then it has high criteria, if $0.3 \leq n \leq 0.7$ then it has medium criteria, and if $n < 0.3$ then has a low criterion.

3. Result and Discussion

The results of the average pretest and posttest data were analyzed by the n-gain test. This n-gain value indicates an increase in students' understanding of ecosystem material. Based on the average pretest and posttest scores, the N-gain value is obtained which is presented in Table 1.

Table 1. Data average value of n-gain

Critical Thinking Skill	N-Gain	Criteria
	0,67	Medium

Based on Table 1. shows that students' critical thinking skills using the STREAM approach have increased with the N-gain value that occurs, which is 0.67 including in the medium category. The criteria for increasing critical thinking specifically based on criteria from low to a high level can be seen in Figure 1.

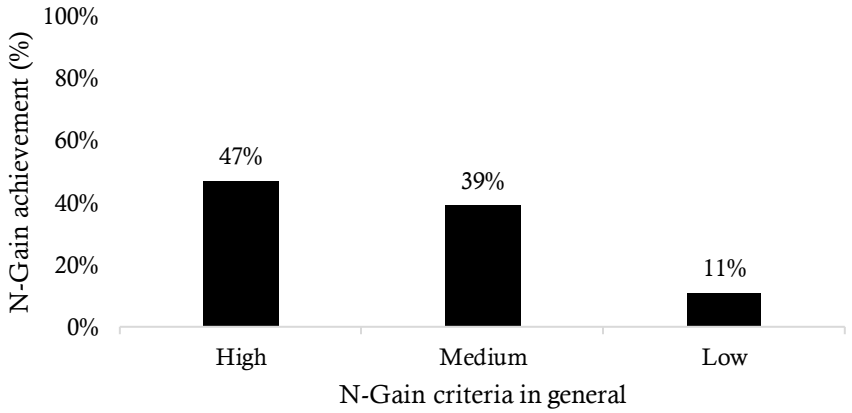

Figure 1. N-gain criteria from low to high level

Based on Figure 1. shows that 47% of students get an n-gain score with high criteria. As many as 39% of students get an n-gain score with medium criteria. While the remaining 11% of students obtained an n-gain score with low criteria.

The number of students who get an improved score with high criteria is indicated because ecosystem learning through the STREAM approach provides opportunities for students to build their own knowledge through independent thinking processes. Students can exchange ideas in dealing with problems. These activities can hone students' critical thinking skills. This is in accordance with Messier's opinion in Hadinugrahaningsih et al. (2017) that STEAM learning not only makes students learn basic theories in learning but will also learn problem solving skills, critical thinking and collaboration skills. Learning with the application of the STEAM approach provides opportunities for students to develop critical thinking skills and students' abilities during the implementation of learning activities.

This is in accordance with several studies that have shown that the STEM and STEAM approaches can improve students' critical thinking skills. As research conducted by Zulfawati and Mayasari (2021) explains that STEM learning is able to train students to think critically, as evidenced by the profile of students' critical thinking abilities distributed on indicators giving a simple score of 94.62 with a very high category, building basic skills of 95.38 very high category. , the indicator provides further explanation of 64.62 in the medium category. Hidayati et al's research (2019) shows that the application of multimedia-STEM education can improve critical thinking skills with an N-gain value of 0.501 which is in the medium criteria. Research by Cahyani and Sulastri (2021) states that with the STEAM approach which is integrated with the PBL model, students' critical thinking skills have improved a lot. N-gain analysis was also carried out on each indicator of critical thinking skills. The results of the N-gain analysis for each of these indicators are presented in Table 2.

Table 2. Average improvement of critical thinking skills indicator

Indicator	N-gain Score	Criteria
Elementary clarification	0,49	Medium
Basic support	0,53	Medium
Inference	0,55	Medium
Advanced clarification	0,52	Medium
Strategy and tactics	0,67	Medium

Based on Table 2 the indicators that experienced the highest average increase were the strategy and tactics indicators of 0.67 which were in the medium criteria. Meanwhile, the indicator that experienced the smallest average increase was the elementary clarification indicator of 0.49 with medium criteria. The indicator that experienced the highest increase was the fifth indicator of strategy and tactics with a score of 0.67 with medium criteria. This indicator experienced the highest increase because at the time of learning students were trained to determine alternative solutions. This is done by students when making products in the form of ecosystem dioramas in learning. At this stage students discuss to determine the theme of the ecosystem diorama that will be made. Students also discussed making ecosystem diorama product designs and the working steps of their manufacture. The discussion encourages students to think critically in determining strategies and tactics. This finding is in accordance with Hadinugrahaningsih et al. (2017) opinion that through the STEAM approach, students can develop problem-solving skills and interact with others. This can make it easier for students to determine the appropriate alternative solutions to problems faced by students.

Meanwhile, the indicator that experienced the lowest increase was the first indicator of elementary clarification with a score of 0.49 with medium criteria. This indicator experienced the lowest increase because students were not used to formulating questions. This is supported by the results of interviews with biology subject teachers. Teachers are not accustomed to applying the steps of the scientific method to students, especially to class X MIPA students because the previous learning process was mostly done online. So that the learning activities carried out tend to aim for students to understand the concept of the material presented. So when working on questions with these indicators, students experience difficulties which makes the scores obtained low.

Basically every indicator has increased. The size of the N-gain value is influenced by several factors. The task of making ecosystem diorama products assisted by a STREAM-based worksheet trains students to formulate questions. The first indicator of critical thinking, namely elementary clarification, can develop in students. Other critical thinking skills can also be developed through learning using the STREAM approach. The PDBU stage (think-design-create-test) will direct students to discuss with each other in groups in order to determine the problem to decide what

ecosystem diorama theme to choose. So that with group discussions students will get used to arguing with each other and are trained to give reasons for their opinions. This is part of the indicator bassic support.

After the discussion, a mutually agreed conclusion was produced. This is able to encourage students to be able to induce and consider the results of induction. These skills are part of the third indicator, namely inference. At the test stage, students are directed to present the results of the ecosystem diorama products that have been made in front of the class. Students will be trained to express opinions in front of many people. In addition, students will be trained to provide advanced clarification. Through the presentation process, students convey the results of their group discussions. This requires the ability to master the concept. So that students are able to give a definition according to the source of learning.

Data analysis of students' critical thinking skills was followed by statistical testing. This test was carried out to prove the research hypothesis. The test that was carried out was the paired sample test with the help of the SPSS version 20 application. It was found that the value of the calculation using the paired sample test found that students' critical thinking skills showed a significant value of α of 0.027 less than α = 0.05. Thus, the results of testing using the paired sample test have the results H_0 rejected and H_1 accepted so that it can be stated that there is a significant difference in the results of students' critical thinking skills before and after being given treatment (Sugiyono, 2019). The difference that occurs is because at least the STREAM approach has several advantages in the process of implementation. The STREAM approach teaches students to think to solve problems actively, creatively and innovatively. Through technology students are able to create their ideas into the latest technology. The STREAM approach can bridge mathematically abstract concepts into technology science, inquiry and art. The integration of arts into STREAM will foster student creativity in creating fun learning tools. The integration of religion aspects into science can enhance students' faith and building the nation's morals. The STREAM approach can provide opportunities for students to be able to apply the learning outcomes obtained into everyday life (Hadinugrahaningsih et al., 2017; Agustina, et al., 2020).

Several studies have shown that the STEM or STEAM approach has a significant effect or difference on critical thinking skills. Sandi's research (2021) shows that the STEM approach has a significant effect on increasing understanding of electroplating concepts, critical thinking skills, and students' cooperative skills. Ahmad's research (2020) explains that there are differences in critical thinking skills after using the STEAM approach, especially in learning experiences. Kang's reaserach (2019) explained that STEAM education in South Korea had a positive impact in the form of increasing teacher professionalism and providing a fairly high increase in students' cognitive and affective learning. Research by Agustina et al (2020) states that the STREAM Approach can equip students' thinking habits.

4. Conclusion

Based on the results of the research and discussion, it can be concluded that students' critical thinking skills can be improved through learning using the STREAM approach in ecosystem material with an increased score of 0.67 with moderate criteria. The calculated value using the paired sample test shows a significance value of α of 0.027 which is less than α = 0.05 meaning that H_0 is rejected and H_1 is accepted so that it can be stated that there is a significant difference in the results of students' creative thinking skills before and after being given treatment. The researcher provides suggestions that are expected to be useful for future researchers who will develop similar research topics.

References

Adeyemi, S. B. (2012). Developing critical thinking skills in students: A mandate for higher education in Nigeria. *European Journal of Educational Research*, *1*(2), 155-161.

Agustina, T. W., Rustaman, N.Y., Riandi, & Purwaningsih, W. (2020). Pendekatan STREAM (science-technology-religion-engineeringarts-mathematics) membekalkan kebiasaan berpikir mahasiswa. *EDUSAINS*, *12*(2), 283-296.

Agustina, T.W., Rustaman, N.Y., Riandi, & Purwaningsih, W. (2018). Traditional biotechnology content as a media in engaging students with system thinking skills. *Scientiae Educatia: Jurnal Pendidikan Sains, 7*(2), 197-217.

Ahmad, D. N., Astriani, M. M., & Alfahnum, M. (2020). Analisis mengukur kemampuan berpikir kritis melalui pembelajaran menggunakan metode STEAM-PjBL. *Diskusi Panel Nasional Pendidikan Matematika*, *6*(1).

Alismail, H. A., & McGuire, P. (2015). 21st century standards and curriculum: Current research and practice. *Journal of Education and Practice*, *6*(6), 150-154.

Asysyifa, D. S. J., Wilujeng, I., & Kuswanto, H. (2019). Analysis of students critical thinking skills using partial credit models (PCM) in physics learning. *International Journal of Educational Research Review*, 245–253.

Barcelona, K. (2014). 21st century curriculum change initiative: A focus on STEM education as an integrated approach to teaching and learning. *American Journal of Educational Research*, *2*(10), 862-875.

Belecina, R. R., & Ocampo Jr, J. M. (2018). Effecting change on students' critical thinking in problem solving. *Educare*, *10*(2).

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In *Assessment and teaching of 21st century skills* (pp. 17-66). Springer, Dordrecht.

Brown, B. (2015). Twenty first century skills: A bermuda college perspective. *Journal of Bermuda Collage*, 1(June), 58–64.

Bybee (2013). The next generation science standards and the life sciences. *NSTA's K12 Journals. 50*(6), 7-14.

Cahyani, G. P., & Sulastri, S. (2021). Pengaruh project based learning dengan pendekatan STEAM terhadap kemampuan berpikir kritis pada pembelajaran online di SMK Negeri 12 Malang. *Jurnal Pendidikan Akuntansi (JPAK)*, *9*(3), 71-78.

Capraro, R. M., & Slough, S. W. (2013). Why PBL? Why STEM? Why now? An introduction to STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach. In *STEM project-based learning* (pp. 1-5). Brill.

Chen, L. (2017). Understanding critical thinking in Chinese sociocultural contexts: A case study in a Chinese college. *Thinking Skills and Creativity, 24*, 140–151.

Creswell, J. W. (2016). *Research design pendekatan kualitatif, kuantitatif, dan mixed*. Yogyakarta: Pustaka Pelajar

D'Alessio, F. A., Avolio, B. E., & Charles, V. (2019). Studying the impact of critical thinking on the academic performance of executive MBA students. *Thinking Skills and Creativity, 31(February),* 275–283.

Ennis, R. H. (1985). A logical basis for measuring critical thinking skills. *Educational leadership*, *43*(2), 44-48.

Erdogan, V. (2019). Integrating 4C skills of 21st century into 4 language skills in EFL classes Vacide Erdoğan. *International Journal of Education and Research, 7*(11), 113-124

Fauzi, A. (2019). Profile of junior high school students' critical thinking skills in answering questions related to biological concepts. *Scientiae Educatia, 8*(1), 51-63. doi:http://dx.doi.org/10.24235/sc.educatia.v8i1.4081

Hadinugrahaningsih, T., Rahmawati, Y., & Ridwan, A. (2017, August). Developing 21st century skills in chemistry classrooms: Opportunities and challenges of STEAM integration. In *AIP Conference Proceedings* (Vol. 1868, No. 1, p. 030008). AIP Publishing LLC.

Hake, R. R. (1998). Interactive engagement v.s traditional methods: six- thousand student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64-74

Hidayati, N., Irmawati, F., & Prayitno, T. A. (2019). Peningkatan keterampilan berpikir kritis mahasiswa biologi melalui multimedia STEM education. *JPBIO (Jurnal Pendidikan Biologi)*, *4*(2), 84-92.

Kang, N. H. (2019). A review of the effect of integrated STEM or STEAM (Science, Technology, Art, adn Mathematics) education in South Korea. *Pacific Science Education, 5*(6), 1-22.

Malik, A., & Ubaidillah, M. (2020). Students critical-creative thinking skill: A multivariate analysis of experiments and gender. *International Journal of Cognitive Research in Science, Engineering and Education*, *8*(S), 49-58.

Maryani, Y., Prasetyorini, P., & Permana, I. (2021). Critical thinking skills of junior high school students in science learning. *Scientiae Educatia, 10*(1), 20-28. doi:http://dx.doi.org/10.24235/sc.educatia.v10i1.8034

Miarti, E., Hasnunidah, N., & Abdurrahman, A. (2021). The effect of learning cycle 5E on critical thinking skills for junior high school students. *Scientiae Educatia, 10*(2), 177-183. doi:http://dx.doi.org/10.24235/sc.educatia.v10i2.9127

Nazila, L., Rosidin, U., Distrik, I., Herlina, K., & Hasnunidah, N. (2019). The effect of applying argument driven inquiry models to the critical thinking skills of students based on gender differences. *Scientiae Educatia, 8*(1), 35-50. doi:http://dx.doi.org/10.24235/sc.educatia.v8i1.4145

NRC. (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century*. Washington, DC: The National Academies Press.

Nupus, D., Pramadi, A., & Mas'ud, A. (2021). Profile students critical thinking skill on reproductive system materials. *Scientiae Educatia, 10*(1), 57-63. doi:http://dx.doi.org/10.24235/sc.educatia.v10i1.8885

Paul, R., & Elder, L. (2019). *The miniature guide to critical thinking concepts and tools*. Rowman & Littlefield.

Pursitasari, I. D., Suhardi, E., Putra, A. P., & Rachman, I. (2020). Enhancement of student's critical thinking skills through science context-based inquiry learning. *Jurnal Pendidikan IPA Indonesia*, 9(1), 97–105. https://doi.org/10.15294/jpii.v9i1.21884

Rahmawati, & Nizam. (2018). Meningkatkan capaian matematika siswa Indonesia: kajian kesalahan konsep nilai tempat. *Indonesian Journal of Educational Assessment*, *1*(1), 1-10.

Rawung, W. H., Katuuk, D. A., Rotty, V. N. J., & Lengkong, J. S. J. (2021). Kurikulum dan tantangannya pada abad 21. *Jurnal Bahana Manajemen Pendidikan*, *10*(1), 29-34.

Roviati, E., Widodo, A., Purwianingsih, W., & Riandi, R. (2019). Development of argumentation-based critical thinking skills tests in microbiology laboratory. *Scientiae Educatia, 8*(1), 76-87. doi:http://dx.doi.org/10.24235/sc.educatia.v8i1.475

Sandi, G. (2021). Pengaruh pendekatan STEM untuk meningkatkan pemahaman konsep elektroplating, keterampilan berpikir kritis dan bekerja sama. *Indonesian Journal of Educational Development*, *1*(4), 579-585.

Saputri, W., Corebima, A. D., Susilo, H., & Suwono, H. (2020). Qasee: A potential learning model to improve the critical thinking skills of pre-service teachers with different academic abilities. *European Journal of Educational Research*, 9(2), 853–864.

Sen, C., Ay, Z. S., & Kiray, S. A. (2018). STEM skills in the 21st century education. *Research highlights in STEM education*, 81-101.

Sitti, S., Sopeerak, S., & Sompong, N. (2013). Development of instructional model based on connectivism learning theory to enhance problem-solving skill in ICT for daily life of higher education students. *Procedia-Social and Behavioral Sciences*, *103*, 315-322.

Sudarisman, S. (2015). Memahami hakikat dan karakteristik pembelajaran biologi dalam upaya menjawab tantangan abad 21 serta optimalisasi implementasi kurikulum 2013. *Florea: Jurnal Biologi dan Pembelajarannya*, *2*(1), 29-35.

Sugiyono. (2019). *Metode penelitian kuantitalif kualitatif dan R&D.* Bandung: Alfabeta.

Suto, I. (2013). 21st Century skills: Ancient, ubiquitous, enigmatic. *Research Matters: A Cambridge Assessment Publication*, *15*, 2-8.

Suwarma, I. R. (2014). *A Research on STEM Education Theory and Practices Method in Japan and Indonesia Using Multiple Intelligence Approach* (Doctoral dissertation, Doctoral Thesis]. Shizuoka: Shizuoka University).

van Laar, E., van Deursen, A. J., van Dijk, J. A., & de Haan, J. (2020). Determinants of 21st-century skills and 21st-century digital skills for workers: A systematic literature review. *Sage Open*, *10*(1), 2158244019900176.

Wang, H. H., Chen, H. T., Lin, H. S., Huang, Y. N., & Hong, Z. R. (2017). Longitudinal study of a cooperation-driven, socio-scientific issue intervention on promoting students' critical thinking and self-regulation in learning science. *International Journal of Science Education*, *39*(15), 2002-2026.

Wati, A. W., & Eka, S. (2015). *Metodelogi Pembelajaran IPA*. Jakarta: PT Bumi Aksara.

Wati, W., Kartimi, K., & Mulyani, A. (2021). Application of biology learning based on local wisdom Cibulan tourism to improve students' critical thinking skills. *Scientiae Educatia, 10*(2), 148-159. doi:http://dx.doi.org/10.24235/sc.educatia.v10i2.9356

Widodo, A. (2021). Pembelajaran ilmu pengetahuan alam dasar-dasar untuk praktik. Banding: UPI Press.

Yuliyani, R., Mulyani, A., Azmi, N., & Chandra, E. (2021). The effectiveness of write-to-learn social-oriented-scientific-issues on students' critical thinking and argumentation skills. *Scientiae Educatia, 10*(1), 01-11. doi:http://dx.doi.org/10.24235/sc.educatia.v10i1.7645

Zulfawati, Z., & Mayasari, T. (2021). Profil kemampuan berpikir kritis peserta didik dengan integrasi STEM. *ORBITA: Jurnal Kajian, Inovasi dan Aplikasi Pendidikan Fisika*, *7*(1), 12-18.