



# The Effectiveness of Learning Progression-based Biotechnology STEM Module to Improve Metacognitive Skills

Siti Muninggar<sup>1\*</sup>, Sarwanto<sup>2</sup>, Murni Ramli<sup>3</sup> 

<sup>1,2,3</sup> Faculty of Teacher Training and Education, Universitas Sebelas Maret, Surakarta, Indonesia

## ARTICLE INFO

### Article history:

Received July 23, 2023

Revised August 08, 2023

Accepted November 10, 2023

Available online November 25, 2023

### Kata Kunci :

Keterampilan metakognitif,  
kemajuan pembelajaran, STEM

### Keywords:

Metacognitive skills, learning  
progression, STEM



This is an open access article under the  
CC BY-SA license.

Copyright ©2023 by Author. Published  
by Universitas Pendidikan Ganesha

## ABSTRAK

Perkembangan zaman menuntut sumber daya manusia yang mampu menghadapi segala situasi dan tantangan dengan penuh percaya diri. Sumber daya ini dapat tercermin dalam keterampilan metakognitif. Adanya keterampilan metakognitif yang rendah mendorong penulis untuk menggunakan modul pembelajaran STEM berbasis progresi bioteknologi. Tujuan dari penelitian ini adalah untuk menganalisis efektivitas modul pembelajaran STEM berbasis progresi bioteknologi untuk meningkatkan keterampilan metakognitif siswa kelas IX SMP pada mata pelajaran IPA. Penelitian ini merupakan penelitian eksperimen semu dengan desain pretest-posttest control group design yang menguji keefektifan modul untuk meningkatkan keterampilan metakognitif siswa kelas IX SMP bidang bioteknologi. Teknik pengambilan sampel yang digunakan adalah simple random sampling yang terdiri dari empat kelas kelas IX. Setiap kelas terdiri dari 32 siswa. Keempat kelas tersebut dikelompokkan menjadi dua, yaitu kelompok kontrol yang terdiri dari satu kelas (32 siswa) dan kelompok eksperimen yang terdiri dari tiga kelas (96 siswa). Data diperoleh dengan melakukan tes analisis dengan uji Independent Sample T-test. Hasil penelitian menunjukkan bahwa modul pembelajaran STEM bioteknologi berbasis progresi mempunyai pengaruh yang cukup untuk meningkatkan keterampilan metakognitif siswa kelas IX SMP.

## ABSTRACT

The times demand human resources that are proficient enough to face all situations and challenges confidently. These resources can be reflected in metacognitive skills. The existence of low metacognitive skills encourages the authors to use the learning progression-based biotechnology STEM module. The aim of this study is to analyze the effectiveness of the learning progression-based biotechnology STEM module to improve the metacognitive skills of the ninth-graders of junior high school in science subjects. This research is quasi-experimental research with a pretest-post-test control group design that tested the effectiveness of the module to improve the metacognitive skills of the ninth-graders of junior high school on biotechnology. The sampling technique used was simple random sampling which consisted of four ninth-grade classes. Each class consisted of 32 students. The four classes were grouped into two, namely the control group consisting of one class (32 students) and the experimental group consisting of three classes (96 students). The data were obtained by conducting tests analyze with an independent sample t-test. The results showed that the learning progression-based biotechnology STEM module had sufficient influence to improve the metacognitive skills of the ninth-graders of junior high schools.

## 1. INTRODUCTION

The times demand increasingly superior human resources to balance with individual skills that are capable of facing various global challenges. Moreover, in the era of Society 5.0, education contributes the largest portion as a determinant of human resources quality. Furthermore, education does not only focus on AI (Artificial Intelligence) but also on the human component as the driving force of education (Barri et al., 2023; Subandowo, 2022). Therefore, it is necessary to have proficient skills so that individuals can deal with all kinds of situations. In line with the development of the era of Society 5.0, 21st-century skills are also very crucial today because the era of Society 5.0 is aligned with 21st-century skills. One of which is metacognitive skills. Metacognitive skills are one of the skills that need to be mastered by individuals. Metacognitive skills should not only be translated as an aspect of thinking but also as a strategic way of thinking that leads to greater academic success. This metacognitive skill plays an important role for students because it can identify ways of thinking to solve problems, control themselves, communicate, and understand the learning they are facing (Daga, 2022; Salsabila & Arif, 2022). Meanwhile, 21st-century skills require a learning process that focuses on every process of discovery and concept development done by students. Thus, metacognitive skills are the answer to the needs of the 21st century in the era of Society 5.0. Regarding metacognitive skills, teachers can develop the skills in various

\*Corresponding author.

E-mail addresses: [siti67@gmail.com](mailto:siti67@gmail.com) (Siti Muninggar)

subjects. One of them is IPA (natural science). The nature of science which consists of processes, products, and attitudes can be students' main capital in acquiring metacognitive skills. Science is not only understood as a collection of knowledge but also as a process of discovery (Aisah, 2020; Kurniawan et al., 2019). This is in line with metacognitive skills which have an important role in managing and controlling individuals' cognitive processes so that they can think more effectively and efficiently. Furthermore, well-trained metacognitive skills can have a positive impact on students because they understand how the learning process is good for them so they can control and evaluate the learning process (Andini & Azizah, 2021; Hermanto et al., 2021). Besides, metacognitive skills also have an influence on students' learning outcomes in biology and their critical thinking skills (Amin et al., 2020; Ismarani & Artayasa, 2023). Additionally, metacognitive skills involve knowledge of mental processes and controlling these processes to achieve goals. Therefore, students need to master metacognitive skills when they learn science.

However, students cannot master metacognitive skills directly. As practitioners, teachers must stimulate them so that students' thinking skills can develop. Teachers can do several things to stimulate students to have metacognitive skills. One of them is by implementing a relevant learning approach such as STEM (Science, Technology, Engineering, and Mathematics). STEM is seen as a learning approach that can improve students' metacognitive skills (Anggraini et al., 2021; Darmawan et al., 2020). Even, STEM-based modules can motivate students to study science. The STEM approach shows students how concepts, principles, science, technology, engineering, and mathematics are integrated to develop products, processes, and systems for human life so that students can understand learning materials more easily because this approach applies real activities around them (Patika et al., 2023; Zulaiha & Kusuma, 2020). This confirms that the STEM approach is seen as the right approach to apply in learning because the nature of natural science is seen as a process, product, and attitude. Science is rich in competencies to explore and understand the natural surroundings scientifically, so metacognitive skills play an important role in mastering these competencies. These metacognitive skills are also seen as awareness in the thinking process. Therefore, if this awareness is realized, students can complete each process of doing assignments that are in line with the indicators of metacognitive skills (Kurniawan et al., 2019; Siregar, 2019). This process is very relevant to the progress of student learning. This learning progress is often referred to as learning progression. Learning progression is a sequence of students' continuous learning at various stages of development, ages, and grade levels. These stages are carried out by students and cover three aspects, namely characteristics, breadth, and depth. Learning progression is also defined as a measurable path that students can follow in the process of developing their knowledge and gaining skills over time. Therefore, it is often called map construction in learning (Choi & Mislevy, 2022; Kula-Kartal, 2022). Students' ability to follow learning progression well enables them to acquire targeted skills. Thus, learning progression is very concerned with a process which is also the main thing in the STEM approach and the nature of science.

Metacognitive skills, which are the main things in the era of Society 5.0 and the 21st century, are a challenge for science teachers because they have to be able to stimulate students' thinking skills and provide them with the full nature of science in classrooms. Unfortunately, reality shows the opposite things. Students' metacognitive skills in science subjects are poor, especially in biotechnology materials. Based on the preliminary study, the percentage of metacognitive skills of the nine-graders of junior high school (SMP) reach 44% which is classified as poor. Whereas, these biotechnology materials reflect the development of science because they link science and technology. In addition, several factors, such as the use of modules that cannot stimulate students' metacognitive skills and the lack of innovative learning model implementation can cause students' poor metacognitive skills. If this continues, it can adversely affect human resources, both from students' and teachers' points of view. As a result, this gives a logical consequence that existing resources can probably create a generation that is weak because they are unable to solve their daily problems which are reflected in their metacognitive skills. Therefore, changes and improvements are needed in science learning activities, especially to improve students' metacognitive skills in biotechnology material. One of them can be conducted by developing modules based on models or innovative learning approaches. The aforementioned description encourages the researchers to develop a learning progression-based biotechnology STEM module to improve the metacognitive skills of the ninth-graders of junior high schools in biotechnology materials. The STEM implementation which results in meaningful learning through systematic integration of knowledge, concepts, and skills can motivate students to have higher-order thinking skills (Deviana & Aini, 2022; Hindrasti et al., 2022). Higher-order thinking skills such as metacognitive skills are reflected in student learning outcomes in which learning outcomes are also inseparable from the processes that individuals go through. Furthermore, the nature of science which consists of processes, products, and attitudes that must be holistic in one lesson provides a logical consequence that student learning progress is very important. Meanwhile, students' thinking abilities at a higher level are formed through learning processes and activities that can stimulate students

to elaborate on the knowledge they have acquired (Soedimardjono & Pratiwi, 2021; Suastra et al., 2021). Thus, it is hoped that the presence of the learning progression-based biotechnology STEM module can provide a natural science learning atmosphere in the classroom that motivates students to acquire high metacognitive skills. Moreover, teachers not only implement innovative learning approaches such as STEM but also guide students with a learning progression map so that the development of students' metacognitive skills can be controlled in every process. These metacognitive skills can be seen from the learning outcomes which are patterns of action, values, understanding, attitudes, appreciation, and skills that are reflected in all individuals' behavior. In this regard, the aims of this study is to analyze the effectiveness of the learning progression-based biotechnology STEM module to improve the metacognitive skills of the ninth-graders of junior high school in science subjects.

## 2. METHODS

This study used experimental methods with a pretest-posttest control group design. This design used an experimental group and a control group which had the same characteristics because they were randomly taken from a homogeneous population (Nana Syaodih Sukmadinata, 2012). The experimental group was treated with the product developed, namely the learning progression-based biotechnology STEM module, while the control group was treated with the old module that was commonly used in schools. The sampling technique at this testing stage was carried out by a simple random sampling technique. This technique was used in taking sample members from a random population regardless of the strata in the population (Sugiyono, 2019). The population of this study was all the ninth-graders at SMPN 1 Klaten, Central Java. The sample in the control class was IX E class consisting of 32 students, and the sample in the experimental class was 96 students coming from three classes: IX A, IX B, and IX C consisting of 32 students each. The data collection technique used in this effectiveness test was a description test technique. This description test was used to measure students' metacognitive skills including planning, monitoring, and evaluating. The data analysis technique used an independent sample t-test. The independent sample t-test was conducted to find out the difference in the mean scores of the experimental group (group 1) which received the treatment using the learning progression based-biotechnology STEM module with the control group (group 2) without the treatment or only used the old modules that were commonly used in schools.

## 3. RESULT AND DISCUSSION

### Results

**Table 1.** The Results of Pre-test and Post-test Scores of the Effectiveness Test

Group	Number of students	Pre-test			Post-test			S	S <sup>2</sup>
		Average	The lowest score	The highest score	Average	The lowest score	The highest score		
Control class	32	23.75	3	43	30.84	9	53	10.064	101.275
Experimental class	96	28.99	4	56	70.12	15	90	17.532	307.376

After knowing the metacognitive skill scores in the pretest and posttest that shown in Table 1, then a different test was carried out using the pretest score. Before using this differential test, a balance test was carried out first to determine the initial abilities of the control and experimental groups. The results of the balance test for the two groups are show in Table 2.

**Table 2.** The Results of the Balance Test Analysis

Tests	Test types	Results	Decision	Conclusion
Normality	<i>Kolmogorov-Smirnov</i>	Control class (Sig. 0.200) Experimental class (Sig.0.54)	H0 is accepted	The data is normally distributed
Homogeneity	<i>Lavene Statistic</i>	Sig. 0.638	H0 is accepted	The data is Homogeneous
Difference Test	<i>Independent Sample t-test</i>	T <sub>count</sub> = -1.605 df = 124 t <sub>tabel</sub> = 1.97928 Sig. 0.111	H0 is accepted	There are no differences (balanced)

Table 2 showed that the normality test for the control class had a significance of 0.200, while the normality test for the experimental class was 0.54. The significance gain was greater than  $\alpha$  (0.05), so  $H_0$  was accepted. Therefore, the data were considered to be normally distributed. Whereas the homogeneity test had a significance of 0.638 which was greater than  $\alpha$  (0.05), so  $H_0$  was accepted and the data were considered homogeneous. While for the independent sample t-test, it was known that t-count = -1.605 which was smaller than  $t_{table} = 1.97928$ . The probability value reached a significance of 0.111 which was greater than  $\alpha$  (0.05). This showed that there was no difference between the control class and the experimental class, so it was considered that the two groups were in a balanced condition. After carrying out the balance test, an effectiveness test was carried out to determine the effectiveness of the learning progression-based biotechnology STEM module in improving the metacognitive skills of the ninth-graders of junior high schools. The effectiveness test was carried out after the analysis requirements were met, namely the normality and homogeneity tests. Table 3 describes the results of the effectiveness test.

**Table 3. The Results of the Analysis of the Effectiveness Test**

Tests	Test Types	Results	Decision	Conclusion
Normality	<i>Kolmogorof-Smirnof</i>	Control class (Sig. 0.149) Experimental class (Sig.0.60)	$H_0$ is accepted	The data is normally distributed
Homogeneity	<i>Lavene Statistic</i>	Sig. 0.605	$H_0$ is accepted	The data is Homogeneous
Difference Test	<i>Independent Sample t-test</i>	$t_{count} = 10.925$ $df = 124$ $t_{table} = 1.97928$ Sig. 0.065	$H_0$ is rejected	There are differences
Effect size test	<i>Cohen's</i>	$d = 0.23$		Sufficient

Table 3 showed that the analysis prerequisite test was fulfilled because the data were normally distributed and homogeneous. Meanwhile, the independent sample t-test showed that the t-count was greater than the t-table. Therefore, it can be concluded that there was a significant difference between the control and experimental classes. Accordingly, the next step was comparing the mean value of the post-test results for the control class and the experimental class written in Table 1. The mean value in the control class reached 30.84, while the average value in the experimental class reached 70.12. Then, the results of the effect size showed the value of  $d = 0.23$  which, according to Cohen's effect size, belonged to the sufficient category. This showed that the use of the learning progression-based biotechnology STEM module had a sufficient effect in improving the metacognitive skills of the ninth graders of junior high schools. Thus, it showed that the learning progression-based biotechnology STEM module was more effective than the former student book.

## Discussion

The results of the research showed that the product developed, namely the learning progression-based biotechnology STEM module, was able to improve students' metacognitive skills effectively. It also provided an understanding that the steps in the learning approach used were able to guide students in obtaining meaningful learning. The learning progression-based biotechnology STEM module implemented in this study applied five steps: problem orientation, formulating problems, brainstorming ideas, testing the best ideas, evaluating solutions, and presenting results (Adi Prayitno & Sugiharto, 2015; Wichaidit et al., 2019). The metacognitive skills in this study consisted of three indicators: planning skills, monitoring skills, and evaluation skills. These three indicators were assessed based on the metacognitive skills assessment guidelines with the percentage conversion described (Andarwulan et al., 2021; Purwanto, 2002). The increase in the metacognitive skills of students who used the learning progression-based biotechnology STEM module was seen in the pretest scores in the control group reaching an average of 23.75 to 30.84 in the posttest. The pretest score in the experimental group reached an average of 28.99 to 70.12 in the posttest. Even though they both increased, it was necessary to do a difference test with an independent sample t-test to find out the differences in students' metacognitive skills in the experimental and control classes. Based on the results of the independent sample t-test, t-count = 10.925 which was greater than  $t_{table} = 1.97928$ , so it can be concluded that there was a significant difference in the control and experimental classes. In addition, the effect size test obtained a value of  $d = 0.23$  which was in the sufficient category. It means that the use of the learning progression-based biotechnology STEM module had a sufficient effect in improving the metacognitive skills of the ninth-graders of junior high schools.

The description of the results of existing research showed that the steps of the learning progression-based biotechnology STEM module were able to guide students to fulfill the indicators of metacognitive skills. The first indicator was planning skills strengthened by the first step of the learning progression-based biotechnology STEM module, namely problem orientation. This problem orientation provided students with a complete picture of the things they had to solve in learning biotechnology. This led them to make study plans that they would carry out. Previous study expressed that the planning process helped individuals to be able to prepare in anticipation of the challenges of the goals to be achieved (Zaroh, 2018). Goal-setting and planning skills actively influenced the independent learning process for individuals. In addition, the process of problem identification strengthened students' knowledge, so they were able to synthesize information they used for discussion (Li et al., 2021; Liu, Y., & Pasztor, 2022). Thus, the STEM syntax improved students' metacognition abilities because it helped students determine problem-solving strategies at the beginning of learning on planning indicators. In addition, they were more responsible, independent, and confident.

Regarding the learning progression-based biotechnology STEM syntax, the second step was to formulate a problem. This activity still determines the student's planning range (the first indicator of metacognitive skills). The activity that students do in this step is to write down various things they want to know after observing the picture at the problem orientation, then students design a project to solve the problem. According to previous study it was important for teachers to provide opportunities for students to understand problems independently, whether in the form of concepts or learning materials because it was important to improve student ability to understand problems (Budianti et al., 2022). Student ability to understand problems, independence, and self-concept influenced and improved student ability in problem-solving. This was confirmed by other study stating that the steps needed to solve the problem were to represent and formulate it after exploring and understanding the problem (Hannania et al., 2022). In line with this, metacognitive teaching could increase students' metacognitive awareness so that students had a positive attitude toward learning which had an impact on their academic achievement (Barri et al., 2023).

After formulating the problem, the next step in learning progression-based biotechnology STEM was brainstorming ideas followed by testing the best ideas. In this step, the second metacognitive indicator, monitoring skill, was very influential on metacognitive skills. The STEM biotechnology based learning progression module gives students space to build hypotheses and prove pre-planned project designs. The existence of this brainstorming idea allowed students to give feedback to their peers and their teachers. Furthermore, previous study stated that to facilitate student cognitive processes, teachers needed to help students by providing feedback internally and externally to create learning communities and metacognition (Zhu et al., 2020). Other study reinforced the opinion stating that teachers needed to stimulate students to participate actively in learning to improve their cognitive abilities (Adinia et al., 2022). Moreover, there were non-cognitive factors that influenced students in solving problems. One of which was the way students learned and the way teachers taught. Therefore, teachers had an important role in improving students' ability to reduce process skills errors and final answer errors. In line with this other study explained that teachers could provide training concerning science process skills for students during the process of building knowledge (Subeki et al., 2022). They created and used information, carried out research processes, and practiced solving problems in the environment. Moreover, the STEM approach could develop students' learning attitudes and skills during the learning process (Melina, 2022; Salsabila & Arif, 2022). Therefore, the use of the learning progression-based biotechnology STEM module carried out in this study was able to improve students' metacognitive skills. The next step in using the learning progression-based biotechnology STEM module was evaluating product solutions followed by presenting the best product results. In this step, students discussed the results and evaluated the process of making conventional and modern biotechnology. In this step, the last indicator of students' metacognitive skills was already working, namely evaluating. Evaluation is a skill to reach the integrity of propositions and the ability to give reasons between opinions, descriptions, and problems with existing theories (Habibah, 2022; Setiyawati et al., 2022; Suriati et al., 2021). One of the evaluation skills in the STEM approach was thinking skills that are in line with existing facts and evidence. This activity can also be considered as a review of facts and concepts that can improve evaluation skills (Agnesa & Rahmadana, 2022; Kiswari et al., 2022). This evaluation skill is also a vehicle for clarifying subject matter. Metacognitive improvement in this study provided an understanding that there were indicators involved in metacognitive skills that could evaluate students' learning processes so that they had deep meaning in what they learned and completed their assignments well (Permana & Setyawan, 2022; Simanjuntak & Sudibjo, 2019).

Therefore, the learning progression-based biotechnology STEM module plays an important role in stimulating students' metacognitive skills because of the conceptual and strategic support that guides

students to have good metacognitive skills. Although the use of this module has been proven to be effective in improving students' metacognitive skills, this module is only limited to biotechnology materials and printed forms. This has a logical consequence in the field of teaching science. It means there is still a need to develop students' metacognitive skills in other science materials and even in other subjects. Considering that metacognitive skills are one of the skills that are needed by individuals in facing global challenges, it is necessary to further develop similar modules with different subjects. Moreover, the progress of the times demands the integration of technology in all fields such as education and teaching. Therefore, digital competence has also become an indispensable skill for educators and researchers, so that module development is carried out not only in printed forms but also in electronic forms.

#### 4. CONCLUSION

Based on the description of the research and development results, it can be concluded that the learning progression-based biotechnology STEM module is effective to improve the metacognitive skills of the ninth-graders of junior high schools. The independent sample t-test showing that the t-count was greater than the t-table can be the evidence. Besides, it can be concluded that there is a significant difference between the control and experimental classes. The results of calculating the effect also showed that this module has sufficient influence in improving the metacognitive skills of the ninth-graders of junior high schools. The learning progression-based biotechnology STEM module can be an alternative for teachers to improve students' metacognitive skills, especially in the ninth-graders of junior high schools. The presence of this module can create a learning environment stimulating metacognitive skills. The available features provide a display of materials, concrete images, and practice questions to keep students motivated to learn.

#### 5. REFERENCES

- Adi Prayitno, B., & Sugiharto, B. (2015). Keefektivan Integrasi Sintaks Inkuiri Terbimbing Dan STAD (INSTAD) Untuk Memperkecil Kesenjangan Keterampilan Metakognisi Siswa Akademik Atas dan Bawah. *Inferensi: Jurnal Penelitian Sosial Keagamaan*, 9(2), 305–328. <https://doi.org/10.18326/infsl3.v9i2.305-328>.
- Adinia, R., Suratno, & Iqbal, M. (2022). Efektivitas Pembelajaran Aktif Berbantuan LKPD Problem Solving terhadap Keterampilan Pemecahan Masalah dan Penguasaan Konsep Biologi Siswa di Sekolah Kawasan Perkebunan Kopi. *Jurnal Inovasi Pembelajaran Biologi*, 3(2), 64–75. <https://doi.org/10.26740/jipb.v3n2.p64-75>.
- Agnesa, O. S., & Rahmadana, A. (2022). Model Problem-Based Learning sebagai Upaya Peningkatan Keterampilan Berpikir Kritis pada Pembelajaran Biologi. *JOTE: Journal On Teacher Education*, 3(3), 65–81. <https://doi.org/10.31004/jote.v3i3.4384>.
- Aisah, S. (2020). Analisis Pemahaman Guru tentang Konsep Hakikat IPA dan Pengaruhnya terhadap Sikap Ilmiah Siswa. *Jurnal AL-Mubin*, 3(1), 16–26. <https://doi.org/10.51192/almubin.v3i1.66>.
- Amin, A. M., Corebima, A. D., Zubaidah, S., & Mahanal, S. (2020). The Correlation Between Metacognitive Skills and Critical Thinking Skills at The Implementation of Four Different Learning Strategies in Animal Physiology Lectures. *European Journal of Educational Research*, 9(1), 143–163. <https://doi.org/10.12973/eu-jer.9.1.143>.
- Andarwulan, T., Al Fajri, T. A., & Damayanti, G. (2021). Elementary teachers' readiness toward the online learning policy in the new normal era during Covid-19. *International Journal of Instruction*, 14(3), 771–786. <https://doi.org/10.29333/iji.2021.14345a>.
- Andini, L., & Azizah, U. (2021). Analisis Korelasi Keterampilan Metakognitif dan Minat Belajar terhadap Hasil Belajar Siswa pada Materi Keseimbangan Kimia. *Jurnal Kependidikan: Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran Dan Pembelajaran*, 7(2), 472–480. <https://doi.org/10.33394/jk.v7i2.3327>.
- Anggraini, L. A., Arif, S., Muna, I. A., & Aristiawan, A. (2021). Pengaruh Model Pembelajaran Numbered Head Together (NHT) Berbasis STEM dalam Meningkatkan Kemampuan Metakognisi. *Jurnal Tadris IPA Indonesia*, 1(2), 219–227. <https://doi.org/10.21154/jtii.v1i2.199>.
- Barri, N. joy C., Lorete, D. C. D., Pacifico, K. A. L., & Valdez, A. G. (2023). Video Demonstration: Effects on Student's Metacognitive Skills in Science. *ASEAN Journal of Science and Engineering Education*, 3(3), 221–228. <https://journal.unnes.ac.id/sju/index.php/usej/article/view/15865>.
- Budianti, D. A., Roshayanti, F., Hayat, M. S., & Syafiq, M. A. (2022). Profil Kemampuan Memecahkan Masalah Peserta Didik MA Darul Muqorrobin pada Pembelajaran Biologi. *Jurnal Kualita Pendidikan*, 3(1), 2774–2156. <https://doi.org/10.51651/jkpv3i1.153>.

- Choi, Y., & Mislevey, R. J. (2022). Evidence centered design framework and dynamic bayesian network for modeling learning progression in online assessment system. *Frontiers in Psychology, 13*, 1–18. <https://doi.org/10.3389/fpsyg.2022.742956>.
- Daga, A. T. (2022). Penerapan Pendekatan Saintifik dalam Kurikulum 2013 untuk Mengembangkan Keterampilan Abad 21 Siswa Sekolah Dasar. *Jurnal Inovasi Dan Riset Akademik, 3*(1), 11–28. <https://doi.org/10.47387/jira.v3i1.137>.
- Darmawan, E., Zubaidah, S., Ristanto, R. H., Zamzami, M. R. A., & Wahono, B. (2020). Simas Eric Learning Model (SELM): Enhance Student' Metacognitive Skill based on The Academic Level. *International Journal of Instruction, 13*(4), 623–642. <https://doi.org/10.29333/iji.2020.13439a>.
- Deviana, T., & Aini, D. F. N. (2022). Learning Progression Guru Sekolah Dasar dalam Pengembangan Konten Soal Asesmen Kompetensi Minimum (AKM). *Jurnal Basicedu, 6*(1), 1285–1296. <https://doi.org/10.31004/basicedu.v6i1.2095>.
- Habibah, M. (2022). Pengembangan Kompetensi Digital Guru Pendidikan Agama Islam Sekolah Dasar dalam Rangka Kurikulum Merdeka. *SITTAH: Journal of Primary Education, 3*(1), 76–89. <https://doi.org/10.30762/sittah.v3i1.11>.
- Hannania, E., Siswono, T. Y. E., & Rahaju, E. B. (2022). Keterampilan Pemecahan Masalah Kolaboratif Siswa Smp Yang Berbeda Adversity Quotient Pada Materi Segiempat. *JPMI (Jurnal Pembelajaran Matematika Inovatif), 5*(2), 471–484. <https://doi.org/10.22460/jpmi.v5i2.10353>.
- Hermanto, Y. B., Meriyati, & Pratiwi, D. D. (2021). Analisis Kemampuan Pemahaman Konsep Peserta Didik Melalui Penerapan Model Pakem Berbantuan Problem Posing ditinjau dari Keterampilan Metakognitif. *Jurnal Cendekia: Jurnal Pendidikan Matematika, 5*(2), 1640–1649. <https://doi.org/10.31004/cendekia.v5i2.666>.
- Hindrasti, N. E. K., Basit, A., & Nevrita, N. (2022). Pengembangan Modul Elektronik Terintegrasi STEM pada Materi Sistem Respirasi Kelas XI. *Jurnal Kiprah, 10*(1), 44–58. <https://doi.org/10.31629/kiprah.v10i1.4553>.
- Ismarani, G., & Artayasa, I. P. (2023). Hubungan Kesadaran Metakognitif dengan Hasil Belajar IPA Biologi. *Journal of Clasroom Action Research, 5*(Special Issue), 174–178. <https://doi.org/10.29303/jcar.v5iSpecialIssue.4081>.
- Kiswari, L., Singgih, S., & Muhlisin, A. (2022). STEM-Based LKPD Development and Contextual Problems to Improve Explanation, Concluding , and Evaluating Skills. *Phenomenon: Jurnal Pendidikan MIPA, 12*(2), 140–157. <https://doi.org/10.21580/phen.2022.12.2.12061>.
- Kula-Kartal, S. (2022). Classroom Assessment: The Psychological and Theoretical Foundations of the Formative Assessment. *International Journal of Assessment Tools in Education, 9*(Special Issue), 19–27. <https://doi.org/10.21449/ijate.1127958>.
- Kurniawan, D. A., Astalini, A., Darmaji, D., & Melsayanti, R. (2019). Students' attitude towards natural sciences. *International Journal of Evaluation and Research in Education, 8*(3), 455–460. <https://doi.org/10.11591/ijere.v8i3.16395>.
- Li, H., Majumdar, R., Chen, M. R. A., Yang, Y., & Ogata, H. (2021). Analysis of Self-Directed Learning Ability, Reading Outcomes, and Personalized Planning Behavior for Self-Directed Extensive Reading. *Interactive Learning Environments, 1–20*. <https://doi.org/10.1080/10494820.2021.1937660>.
- Liu, Y., & Pasztor, A. (2022). Effects of problem-based learning instructional intervention on critical thinking in higher education: A meta-analysis. *Thinking Skills and Creativity, 45*(9), 1–21. <https://doi.org/10.1016/j.tsc.2022.101069>.
- Melina, S. R. I. (2022). Pendekatan Stem Berbasis Projek Pada Materi Sel Volta Dari Bahan Alami Untuk Mengembangkan Ketrampilan 4C Dan Meningkatkan Hasil Belajar Kimia. *SENTRI: Jurnal Riset Ilmiah, 1*(3), 613–619. <https://doi.org/10.55681/sentri.v1i3.263>.
- Nana Syaodih Sukmadinata. (2012). Metode Penelitian Pendidikan. In *Bandung: Alfabeta*.
- Patika, S., Rohana, & Surmilasari, N. (2023). Pengembangan Bahan Ajar IPA Berbasis Pendekatan STEM pada Materi Rangkaian Listrik Kelas VI SD. *JEMS (Jurnal Edukasi Matematika Dan Sains), 11*(2), 544–554. <https://doi.org/10.25273/jems.v11i2.15817>.
- Permana, F. H., & Setyawan, D. (2022). Integrasi polysynchronous learning dengan problem-based learning untuk meningkatkan keterampilan metakognitif. *JINoP (Jurnal Inovasi Pembelajaran), 8*(2), 244–255. <https://doi.org/10.22219/jinop.v1i1.2441>.
- Purwanto, N. (2002). *Prinsip-prinsip dan Teknik Evaluasi Pengajaran*. PT Remaja Rosdakarya.
- Salsabila, M. I., & Arif, S. (2022). Efektivitas Model Pembelajaran Kooperatif Jigsaw Berbasis STEM (Science, Technology, Engineering, And Mathematic) Terhadap Kemampuan Metakognisi. *PENDIPA Journal of Science Education, 6*(3), 822–831. <https://doi.org/10.33369/pendipa.6.3.822-831>.
- Setiyawati, E., Fauziati, E., Darsinah, Minsih, & Prastiwi, Y. (2022). Problem Solving Errors in Mathematics

- Story Questions. *Jurnal Pendidikan Indonesia*, 11(3), 466–479. <https://doi.org/10.23887/jpiundiksha.v11i3.46980>.
- Simanjuntak, M. F., & Sudibjo, N. (2019). Meningkatkan Keterampilan Berpikir Kritis Dan Kemampuan Memecahkan Masalah Siswa Melalui Pembelajaran Berbasis Masalah [Improving Students' Critical Thinking Skills and Problem Solving Abilities Through Problem-Based Learning]. *JOHME: Journal of Holistic Mathematics Education*, 2(2), 108. <https://doi.org/10.19166/johme.v2i2.1331>.
- Siregar, S. (2019). Analisis Keterampilan Metakognitif dan Sikap Ilmiah Siswa Melalui Metode Pembelajaran Inkuiri. *BIOTIK: Jurnal Ilmiah Biologi Teknologi Dan Kependidikan*, 7(2), 141. <https://doi.org/10.22373/biotik.v7i2.5665>.
- Soedimardjono, F. P. P., & Pratiwi. (2021). Cooperative Learning Model with Jigsaw Type Improves Students' Sciences Process Skills and Learning Outcomes. *JPI (Jurnal Pendidikan Indonesia)*, 10(1), 172. <https://doi.org/10.23887/jpi-undiksha.v10i1.25203>.
- Suastra, I. W., Rapi, N. K., Yasa, P., & Arjana, I. G. (2021). Elaborating Indigenous Science Content into Science Learning Process: A New Science Instructional Model to Develop Students' Local Wisdom-Based Characters and Higher Order Thinking Skills. *JPI (Jurnal Pendidikan Indonesia)*, 10(3), 516. <https://doi.org/10.23887/jpi-undiksha.v10i3.31176>.
- Subandowo, M. (2022). Teknologi Pendidikan di Era Society 5.0. *Sagacious Jurnal Ilmiah Pendidikan Dan Sosial*, 9(1), 24–35. <https://rumahjurnal.net/sagacious/article/view/1139>.
- Subeki, R. S., Astriani, D., & Qosyim, A. (2022). Media simulasi PhET berbasis inkuiri terbimbing materi getaran dan gelombang terhadap peningkatan keterampilan proses sains peserta didik. *Pensa E-Jurnal: Pendidikan Sains*, 10(1), 75–80. <https://ejournal.unesa.ac.id/index.php/pensa/article/view/41459>.
- Sugiyono. (2019). *Metode Penelitian & Pengembangan (Research and Development/R&D)*. Alfabeta.
- Suriati, A., Sundaygara, C., & Kurniawati, M. (2021). Analisis Kemampuan Berpikir Kritis Pada Siswa Kelas X SMA Islam Kepanjen. *Rainstek Jurnal Terapan Sains Dan Teknologi*, 3(3), 176–185. <https://doi.org/10.21067/jtst.v3i3.6053>.
- Wichaidit, S., Assapun, S., Putwattana, N., Joongpan, C., Tabthong, S., & Chowicharat, E. (2019). The STEM flower: The designing tool for effective STEM instruction. *AIP Conference Proceedings*, 2081(March). <https://doi.org/10.1063/1.5094013>.
- Zaroh, S. (2018). The Impact of Experimental Learning Techniques in Improving The Capability of Career Planning for Students. *Islamic Guidance and Counseling Journal*, 1(2), 45–52. <https://doi.org/10.25217/igcj.v1i2.233>.
- Zhu, M., Bonk, C. J., & Doo, M. Y. (2020). Self-directed learning in MOOCs: exploring the relationships among motivation, self-monitoring, and self-management. *Educational Technology Research and Development*, 68(5), 2073–2093. <https://doi.org/10.1007/s11423-020-09747-8>.
- Zulaiha, F., & Kusuma, D. (2020). Pengembangan Modul Berbasis STEM untuk Siswa SMP. *Jurnal Pendidikan Fisika Dan Teknologi*, 6(2), 246–255. <https://doi.org/10.29303/jpft.v6i2.2182>.