Improving Creative Thinking Skill on Biotechnology Material Through The Effectiveness of Project Based Learning-STEM E-Module Provided with Formative Assessment

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Abstract. The research aimed to explore students' creative thinking skills on biotechnology material through the effectiveness of Project Learning STEM E-Module provided with formative assessments (PjBL-STEM-AF). The research was carried out by applying a quasi-experimental design with a non-equivalent pretest-posttest. The experimental group received learning on the application E-Modules PjBL-STEM-AF, while the control group received conventional learning treatment. The test instrument in this study was in the form of a Biotechnology Creative Thinking Ability Test, which consisted of 8 written essay questions with a reliability of 0.87. Quantitative data obtained were analyzed using descriptive statistics, normality, and homogeneity tests, different tests, and N-gain. The results of the study showed that the student's creative thinking skills in the PjBL-STEM-AF class were significantly better than the conventional class. In addition, the experimental class obtained a medium N-gain category, while the control class was in the low category. Therefore, the experimental class was effective in training students' creative thinking skills. In terms of creative thinking indicators, for the experimental and control groups, the highest increase was obtained in the fluency indicator, while the lowest was in the originality and elaboration indicators. Recommendations for further research are to add "Art" aspects to the STEM approach so that students' creative thinking skills can be further improved.

Keywords: Biotechnology, Creative Thinking, PjBl-STEM, Formative Assessment.

1 Introduction

Science learning including process, product, attitude, and application components, are visible when studying biotechnology [1]. iotechnology discusses the application of scientific and technological principles by using organisms to create products or services [2], so that it can be used as an intermediary for students in mastering science and technology [3]. However, biotechnology materials are very complex and often

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lead to disputes [4][5] as they relate to biochemistry, genetics, microbiology, physics, and mathematics. The current study of biotechnology is very important to learn because it has become a major area of world economic and technological interest. However, in reality, the literature dealing with the topic of biotechnology education was still small [5][6].

Biotechnology is applicable and and abstract [7], but students have not mastered it optimally. In this case, students only completed 68.46%, so they still had difficulty in understanding the meaning of biotechnology, distinguishing and understanding conventional biotechnology from modern biotechnology, understanding microorganisms that play a role in the process of making biotechnology products, understanding engineering and reproductive technology, and understanding tissue culture [8]. Meanwhile, concept mastery supports students' creative thinking [9]. Classified as 21st-century skills [6][10], creative thinking could be interpreted as a way of thinking that is capable of producing new things when learning or understanding a concept, definition, or work of art, and being able to practice new creative skills [11] and consisted of indicators of fluency, flexibility, originality, and elaboration [12][13]. Creative thinking was required by students in formulating information regarding applications and providing solutions to problem-solving [14], i.e. solving the bad impacts of biotechnology [15]. However, The Global Creativity Index 2015 still ranks Indonesian students 115th out of 139 countries [16]. Also, other research shows that students still have an average flexibility indicator of 46.8%, and on biotechnology material, the N-Gain results of student's creative thinking skills are not optimal [15]. Some of the causes of this include the lack of no implementation of the textbook that supported students' creative thinking skills [17], the lack of science practicum activities [18] and the learning process also did not emphasize creative thinking skills [19], and biotechnology learning which still tends to memorize instead of understanding concepts [20].

In recent years, efforts to increase creative thinking have led to the application of learning models and teaching materials, such as printed modules [21], Guided Inquiry Laboratory-based biotechnology material modules [22], Socio Scientific Issue-based textbooks [23], as well as Bio-entrepreneurship student worksheets on conventional biotechnology material [24]. However, its application has not facilitated students in studying modern biotechnology, which was considered difficult and abstract because they learned something molecular [25]. This problem could be solved by presenting text, images, videos, and animations in the E-Module [26]. E-Module was a module that was presented in an electronic form that could be provided with images, texts, animations, and even videos [26]. E-Module was more accessible and portable, then students could learn according to their needs [27].

Some learning has been done to improve creative thinking skills, including local potential-based learning on static fluid material with low N-Gain [28], and Blended Learning on blood circulation system material with moderate N-Gain results [29]. However, the application of this method did not accommodate applicative material. Referring to the characteristics of applicable and abstract biotechnology materials [7][30], Project Based Learning (PjBL) was successfully applied to acid-base solution material [31] and biotechnology [32]. PjBL can encourage students' creativity and out-of-the-box thinking [33], making students active in producing project products that can improve creative thinking [34][35]. In PjBL, students understand concepts through the process of making products [32]. Meanwhile, in the STEM approach, students did an engineering design process to produce the best product [36]. In biotechnology material, making this product involves other materials, namely biology, technology, and engineering [37]. Aspects of Science, Technology, Engineering, and Mathematics could be fulfilled by applying the STEM approach [38]. Therefore, the PjBL model needed to be integrated with STEM. The STEM approach encouraged students to explore through project activities [39]. Students could investigate deeper issues with PjBL-STEM learning [40].

The application of PjBL-STEM could prepare students to engage in meaningful learning through the process of project activities so that they could be more actively involved [41]. Project-based assessment is conducted thoroughly during learning [42]. Therefore, formative assessment is needed [43]. Formative assessment occurred during the learning process and was used to determine student learning progress in order to obtain information about the way the teacher developed learning and teaching-learning processes that were carried out normally [44]. Students engaged in learning activities and gained an understanding of concepts through feedback [1] therefore the teacher could determine the procedure of continuous learning [45]. However, PjBL-STEM learning that was supplemented by formative assessments was still rarely done.

Based on the description of the problems above, it was necessary to apply learning according to the characteristics of biotechnology by reviewing the learning process. Therefore, the purpose of this research was to find out and analyze the improvement of students' creative thinking skills on biotechnology material through effectivity test of project-based learning-STEM e-module provided with formative assessments.

2 Method

The research design used in the implementation of this study is a quasi-experimental design with a non-equivalent pretest and posttest to be compared [46]. The research was conducted on ninth-grade students at a junior high school in Malang who were studying biotechnology. Based on the existing population, the research sample was selected by non-random assignment [47]. Therefore, two classes were selected as samples, namely an experimental class with 31 students taught with PjBL-STEM-AF-based E-Modules and a control class with 31 students taught with conventional learning.

The instruments applied to experimental class learning were PjBL-STEM-based E-Modules provided with formative assessments that had been developed by Silfiyah et al. (2021) [48]. The appropriateness results of E-Module products were successively based on the validation test results of material experts, media experts, and teachers of 94.83%, 99.33%, and 91.67%; therefore, they were very suitable for use as teaching materials [48].

Implementation of project-based learning activities in school and assignments in student learning activities in the E-Module had been integrated with the PjBL-STEM syntax, namely Identify Problems and Constraints, Research, Ideate, Analyze Ideas, Build, Test and Refine, and Communicate and Reflect [49]. The E-Module was also equipped with key strategies from formative assessment according to Thompson

(2008) [50] that included sharing learning, questioning, feedback, peer assessment, and self-assessment [51]. In addition, the E-Module was also equipped with indicators of creative thinking skills, including fluency, flexibility, originality, and elaboration, according to Baer (1993) [52]. The Identify Problem and Constraints syntax which is thick with science aspects is realized in the “Let's Identify” activity with the involvement of key sharing learning strategies to build flexibility indicators. The Research syntax is carried out through the "Let's Investigate" activity with the involvement of science aspects designed to develop flexibility indicators. The Ideate syntax with the involvement of technology aspects focuses on the "Let's develop ideas" activity and is designed to build the fluency indicator. The "Let's Analyze" activity, which corresponds to the Analysis Ideas syntax and involves aspects of Science and Technology and key questioning strategies, provides opportunities for students to carry out project tasks and builds the originality indicator. The Build syntax is realized in the "Let's Make" activity involving all aspects of STEM and the key strategies of peer assessment and self-assessment and is designed to build the elaboration indicator. The Test and Refine syntax in the "Let's Test and Refine" activity involves the key strategy of feedback and is designed to achieve the elaboration indicator. Finally, the Communicate and Reflect syntax carried out in the "Let's Presentation and Reflection" activity involving feedback, self-assessment and, peer assessment is able to increase the elaboration indicator.

The test instrument in this study was The Biotechnology Creative Thinking Ability Test (BCTA Test), which was composed of 8 written essay questions with details on two items about each indicator of creative thinking. Before conducting the research, instrument validation was carried out first. It consisted of device validation and question validation by using a Likert scale with very valid results. Content validation and construct validation were conducted by 2 thesis supervisors and 2 science teachers. Furthermore, the test instrument was tested empirically on 128 students who had studied biotechnology to determine its validity and reliability values using SPSS software. This empirical test produces valid BCTA Test items and has a Cronbach's alpha reliability of 0.87. The research data from the pre and post-test results were analyzed through the categorization of creative thinking completeness [53], 2-group t-test [54], and N-Gain improvement [53]. The learning model with E-Module based on PjBL-STEM-AF is said to be effective in improving students' creative thinking skills if the experimental class is significantly better than the control class, and the experimental class obtains an N-gain of at least medium category.

3 Results and Discussion

The statistical description of the pretest, posttest, pre-posttest improvement, and N-gain data, respectively for the experimental and control classes, was 35.79 (6.34), 71.88 (8.72), 36.09 (9.43), and 0.56 (Medium); and 40.32 (9.10), 53.73 (11.84), 13.41 (7.99), and 0.23 (Low). It appears that both classes have almost the same pretest score, but the experimental class has a higher post-test score than in the control class so that the experimental class has a higher pre-post-test score improvement than the control class. The Shapiro-Wilk normality test results for the creative thinking improvement data are Sig. 0.311 for the experimental class, and Sig. 0.673 for the control class so that both classes have a normal distribution. While the homogeneity test results are Sig. 0.210 so that both classes have homogeneity of variance.

The results of the independent t-test showed Sig. (2-tailed) <0.001. This means that the increase in creative thinking in the experimental class is significantly higher than the control class. Thus, the PjBL-STEM-AF learning model is able to improve students' creative thinking skills. Furthermore, the results of the N-gain calculation show that the experimental class obtained 0.56 (Medium), and the control class 0.23 (Low). Thus it can be said that the PjBL-STEM-AF learning model is effective in improving students' creative thinking skills. The results of this study are supported by previous research, including PjBL-STEM learning is able to achieve an increase in students' creative thinking skills and has a major influence [55], and could be useful for students to increase their learning outcomes from low to higher results and be able to reduce their achievement gaps [56], and with the addition of formative assessments students be able to describe and provide solutions to the problems given [57]. The results of student products can be used to interpret the material that has been taught and also to achieve learning objectives [58]. However, this research has the advantage of previous research, namely the addition of Formative Assessment in the PjBL-STEM learning model.

In this research, the N-gain calculation results for learning activity 1: Conventional and modern biotechnology, for the experimental and control classes, were 0.61 (Medium) and 0.23 (Low), respectively. For learning activity 2: The impact of conventional and modern biotechnology, for the experimental and control classes, respectively, are 0.51 (Medium) and 0.23 (Low). It appears that in both activities the experimental class achieved a medium category N-gain which was higher than the low category control class. In the experimental class, the N-gain of Activity 1 was higher than Activity 2, but the control class obtained the same N-gain for both activities. This difference may be due to the experimental class learning series that had been arranged for each sub-material. There were project-making activities according to the problems presented in the E-Module. The first project was about making nata with natural ingredients and fruit juice, while the second project was about making biogas and organic fertilizer as a solution to the impact of biotechnology waste products. In this research, students showed a high sense of responsibility related to the assignments presented. This was because E-Modules provided with formative assessments could help students move from group regulation to independence. Therefore, this situation was capable of demanding students' abilities to be able to describe the problems presented; therefore, cognitive structures could grow and play a role in helping to build student knowledge itself so it could foster problem-solving skills better [59]. Another advantage of implementing formative assessment in Project Based Learning-STEM learning was that it was able to develop all individual students, stimulate students' creative abilities, and build individual groups that have a sense of responsibility [60].

This study used four indicators of creative thinking skills. The results of obtaining an increase in students' creative thinking based on each indicator in the experimental and control class groups, respectively for the indicators of fluency, flexibility, originality, and elaboration, were 0.83 (high), 0.54 (medium), 0.46 (medium), and 0.48 (medium); and 0.32 (medium), 0.19 (low), 0.25 (low), and 0.12 (low). It appears that the increase in each creative thinking indicator in the experimental class is one level higher than the control class. The experimental class fluency indicator was categorized as high and the control class as medium. This means that students already had the skills to express their ideas smoothly and were able to provide many ideas from their own thoughts. Students were able to provide a number of answers, and were fluent in expressing many ideas [61]. Also, if students already had very good mastery of the materials, they were able to create many ideas on a problem, so their creative thinking skills could increase [62]. Related to biotechnology material, students are able to provide various answers and create many ideas based on problems related to biotechnology material [63]. Whereas control class students have not been able to provide ideas fluently and have not been able to solve problems well from the ideas they have. This means that students only answer questions with makeshift answers [64].

The experimental class flexibility indicator is categorized as medium and the control class is low. This is in line with previous research that STEM learning from home with PjBL can improve flexibility indicators [65]. The flexibility aspect was seen when students were able to provide varied ideas for a problem and were able to present concepts differently [18]. Experimental class students were able to provide solutions and hypotheses in solving the impact of using chemical fertilizers, namely in the form of making fermented compost, biofertilizer, and utilizing the remaining biogas sludge. The level of medium to high flexibility indicators is closely related to the number of ideas that students can create and the answers produced must be varied [66]. Open (divergent) questions could be used to develop students' flexibility skills to give correct answers from various points of view [67].

The originality indicator of the experimental class is categorized as medium and the control class is low. This is in line with previous research that STEM learning from home with PjBL can improve originality indicators in the medium category [65]. This condition occurs because in the E-module there are project learning instructions, examples of creative thinking evaluation questions, and structured tasks that can condition students to be able to design simple projects. Students who had good originality skills would be able to address existing problems, create their own ways that had not been thought of before, and be innovative in solving them [63]. A student with creative abilities would be able to improvise to find and create novelty and unique things [68]. In this study, experimental students have been able to provide solutions to the problem of soybean skin waste, namely making it organic fertilizer, processing it into nata products, fermented food for animals, and bread flour. It appears that in solving the problems given, students use their own methods and have not been thought of by others [69]. However, the increase in students' originality indicator is the lowest. It may be because students are still unfamiliar with this PjBL-STEM-AF learning model. Therefore, it is recommended to add the "Art" aspect to the STEM approach. Meanwhile, control class students with low originality indicator improvement still have difficulty in providing original ideas [70].

The elaboration indicator of the experimental class is categorized as medium and the control class is low. The result of this study is supported by previous research that PjBL learning is able to improve the elaboration indicator medium category [71]. Students with good elaboration abilities did not just give sober answers when facing problems; they were also able to present concise, precise, clear, logical arguments that were packaged in the form of good presentations or explanations, so others could more easily understand the answer [63]. In this study, PjBL-STEM-AF learning was able to train students to solve or answer a problem by carrying out detailed procedures and trying to develop ideas for solving problems in detail. Students are able to answer questions and solve household waste problems with detailed steps and develop their ideas in the form of making solid, liquid, and biogas fertilizers in one series of tools.

4 Conclusion

Based on the findings and discussions, it can be concluded that the PjBL-STEM-AF learning model is effective in improving students' creative thinking skills. This is characterized by students in PjBL-STEM-AF learning being able to improve creative thinking skills significantly higher than conventional learning, and being able to obtain a medium category N-gain increase. In terms of creative thinking indicators, for the experimental and control groups, the highest increase was obtained in the fluency indicator, while the lowest was in the originality and elaboration indicators. The increase in the originality indicator of experimental class students was the lowest. This may be due to the fact that students are still unfamiliar with this PjBL-STEM-AF learning model. Recommendations for further research are to add "Art" and "Religion" aspects to the STEM approach in the E-Module to build students' creative thinking skills better.

References

1. I. P. Sari, V. R. Mustikasari, and N. Pratiwi, “Pengintegrasian Penilaian Formatif dalam Pembelajaran IPA Berbasis Saintifik terhadap Pemahaman Konsep Peserta Didik,” *J. Pendidik. IPA Veteran*, vol. 3, no. 1, pp. 51–61, 2019.
2. N. Nurlaely, A. Permanasari, and R. Riandi, “Student’s STEM Literacy in Biotechnology Learning at Junior High School,” *J. Phys. Conf. Ser.*, vol. 895, no. 1, p. 012155, Sep. 2017, doi: 10.1088/1742-6596/895/1/012155.
3. A. P. P. Sari, M. Amin, and B. Lukiati, “Buku Ajar Bioteknologi Berbasis Bioinformatika dengan Model ADDIE,” *J. Pendidik. Teor. Penelitian, dan Pengemb.*, vol. 2, no. 6, pp. 768–772, Jun. 2017, doi: 10.17977/JPTPP.V2I6.9334.
4. S. Riani, I. Hindun, and M. A. Krisno Budiyanto, “Pengembangan Media Pembelajaran Berbasis Multimedia Interaktif Untuk Meningkatkan Pemahaman Materi Bioteknologi Modern Siswa Kelas Xii Sma,” *J. Pendidik. Biol. Indones.*, vol. 1, no. 1, pp. 9–16, 2015, doi: 10.22219/jpbi.v1i1.2298.
5. N. M. Bahri, D. DeWitt, and S. Siraj, “Students’ Biotechnology Literacy: The Pillars of STEM Education in Malaysia,” *Eurasia J. Math. Sci. Technol. Educ.*, vol. 10, no. 3, pp. 175–184, 2014, doi: 10.12973/eurasia.2014.1074a.
6. M. Halimah, A. Rahmat, and S. Redjeki, “Biotechnology learning profile biology in FKIP Biology Education Study Program Pasundan University Bandung Indonesia,” *J. Phys. Conf. Ser.*, vol. 1521, no. 4, 2020, doi: 10.1088/1742-6596/1521/4/042031.
7. S. Riani, I. Hindun, and A. K. Budiyanto, “Pengembangan Media Pembelajaran Berbasis Multimedia Interaktif untuk Meningkatkan Pemahaman Materi Bioteknologi Modern Siswa Kelas XII SMA,” *J. Pendidik. Biol. Indones.*, vol. 1, no. 1, pp. 9–16, 2015.
8. Sumiar, R. G. P. Panjaitan, and E. S. Wahyuni, “Upaya Meningkatkan Hasil Belajar Siswa Melalui Pembelajaran Direct Instruction pada Materi Bioteknologi Kelas IX B SMP,” *J.*

Pendidik. dan Pembelajaran Khatulistiwa, vol. 3, no. 12, Dec. 2014, doi: 10.26418/JPPK.V3I12.8110.
9. G. A. Permana, Parno, A. Hidayat, and M. Ali, "Improving Creative Thinking Skill of Fluid Dynamic Through IBL-STEM with Formative Assessment," *AIP Conf. Proc.*, vol. 2330, no. 1, pp. 1–8, 2021, doi: 10.1063/5.0043128.
10. Y. Yustina, I. Mahadi, Z. Zulfarina, and ..., "The Effect of Constructivism-Based STEM on Students' Creative Thinking Skills in Biotechnology Learning," … …, pp. 9727–9735, 2021, [Online]. Available: http://bircu-journal.com/index.php/birci/article/view/2995
11. Wahyudi and A. Winanto, "Development of Project-based Blended Learning (PjB2L) Model To Increase Pre-Service Primary Teacher Creativity," *J. Educ. Sci. Technol.*, vol. 4, no. 2, pp. 91–102, Aug. 2018, doi: 10.26858/EST.V4I2.5563.
12. D. Primaningsih and W. Murtafiah, "Enhancing Creative Thinking Ability of Students in Probability Topics Through React Learning," *JIPM (Jurnal Ilm. Pendidik. Mat.*, vol. 8, no. 1, pp. 58–64, Sep. 2019, doi: 10.25273/JIPM.V8I1.4443.
13. X. Gu, A. Dijksterhuis, and S. M. Ritter, "Fostering children's creative thinking skills with the 5-I training program," *Think. Ski. Creat.*, vol. 32, pp. 92–101, Jun. 2019, doi: 10.1016/J.TSC.2019.05.002.
14. T. Doleck, P. Bazelais, D. J. Lemay, A. Saxena, and R. B. Basnet, "Algorithmic thinking, cooperativity, creativity, critical thinking, and problem solving: exploring the relationship between computational thinking skills and academic performance," *J. Comput. Educ. 2017 44*, vol. 4, no. 4, pp. 355–369, Aug. 2017, doi: 10.1007/S40692-017-0090-9.
15. N. Layyina, R. Agustini, and S. Indana, "Efektifitas Perangkat Pembelajaran IPA Berorientasi Model Inkuiri untuk Melatihkan Keterampilan Berpikir Kreatif Siswa," *JPPS (Jurnal Penelit. Pendidik. Sains)*, vol. 10, no. 2, pp. 2005–2015, Jun. 2021, doi: 10.26740/JPPS.V10N2.P2005-2015.
16. H. R. Dewi, T. Mayasari, and J. Handhika, "Increasing Creative Thinking Skills And Understanding Of Physics Concepts Through Application Of STEM-Based Inquiry," *J. Penelit. Pendidik. IPA*, vol. 4, no. 1, pp. 25–30, 2019.
17. F. A. Almuharomah, T. Mayasari, and E. Kurniadi, "Pengembangan Modul Fisika STEM Terintegrasi Kearifan Lokal 'Beduk' untuk Meningkatkan Kemampuan Berpikir Kreatif Siswa SMP," *Berk. Ilm. Pendidik. Fis.*, vol. 7, no. 1, pp. 1–10, Feb. 2019, doi: 10.20527/BIPF.V7I1.5630.
18. G. Istiqhfarini, U. S. Hastuti, and D. Listyorini, "Handout Bioteknologi SMK ' Pemanfaatan Dami Nangka sebagai Bahan Dasar Pembuatan Nata ' Meningkatkan Kemampuan Berpikir Kreatif Siswa," *J. Pendidik.*, pp. 1149–1153, 2019.
19. E. Sulistiyono, S. Mahanal, and M. Saptasari, "Peningkatan Keterampilan Berpikir Kreatif dan Hasil Belajar Kognitif Melalui Pembelajaran Biologi Berbasis Speed Reading-Mind Mapping (SR-MM)," *J. Pendidik.*, pp. 1226–1230, 2017.
20. P. W. Hidayat and D. B. Widjajanti, "Analisis kemampuan berpikir kreatif dan minat belajar siswa dalam mengerjakan soal open ended dengan pendekatan CTL," *J. Pendidik. Mat.*, vol. 13, no. 1, pp. 63–75, 2018.
21. M. Soviana, S. Gummah, and L. Habiburahman, "Pengembangan Modul Berbasis Masalah untuk Meningkatkan Keterampilan Berpikir Kreatif Siswa," *Lensa J. Kependidikan Fis.*, vol. 5, no. 2, pp. 41–47, Dec. 2017, doi: 10.33394/J-LKF.V5I2.137.
22. A. K. Nurjanah, S. Sajidan, and P. Karyanto, "Pengembangan Modul Biologi Berbasis Model Guided Inquiry Laboratory pada Materi Bioteknologi," *INKUIRI J. Pendidik. IPA*, vol. 5, no. 3, pp. 26–39, Oct. 2016, doi: 10.20961/INKUIRI.V5I3.9438.
23. I. Budi Santoso, J. Waluyo, and S. Hariyadi, "Effectiveness of Science Textbooks Based on Socio-Scientific Issues in Biotechnology Materials To Improve Creative Thinking Ability," *Int. J. Adv. Res.*, vol. 08, no. 04, pp. 140–144, Apr. 2020, doi: 10.21474/IJAR01/10757.

24. S. Nurfaizah and S. Indana, "Keefektifan Lembar Kegiatan Peserta Didik (LKPD) Berbasis Bioentrepreneurship pada Materi Bioteknologi Konvensional untuk Melatihkan Keterampilan Berpikir Kreatif," *J. BioEdu*, vol. 8, pp. 208–217, 2019, Accessed: Oct. 14, 2022. [Online]. Available: https://ejournal.unesa.ac.id/index.php/bioedu/article/view/28832
25. S. M. Rangkuti, F. Harahap, and S. Edi, "Analisis Pengetahuan dan Ketuntasan Siswa pada Materi Bioteknologi di SMA Negeri Se-Kota Binjai," *J. Pendidik. Biol.*, vol. 5, no. 3, pp. 180–186, Aug. 2016, doi: 10.24114/JPB.V5I3.4318.
26. I. Laili, . G., and . U., "Efektivitas Pengembangan E-Modul Project Based Learning pada Mata Pelajaran Instalasi Motor Listrik," *J. Ilm. Pendidik. dan Pembelajaran*, vol. 3, no. 3, pp. 306–315, Nov. 2019, doi: 10.23887/JIPP.V3I3.21840.
27. W. Widayanti, A. R. Sinensis, T. Firdaus, E. Effendi, and A. U. Sholikahah, "Local Wisdom-Based E-Module with Project-Based Learning Model: Enriching Energy Topic in Physics Learning," *undefined*, vol. 5, no. 1, pp. 77–85, Mar. 2022, doi: 10.24042/IJSME.V5I1.11339.
28. S. Sarah, "Peningkatan Keterampilan Berpikir Kreatif Melalui Pembelajaran Fisika Berbasis Potensi Lokal," *JIPFRI (Jurnal Inov. Pendidik. Fis. dan Ris. Ilmiah)*, vol. 2, no. 2, pp. 84–94, Nov. 2018, doi: 10.30599/JIPFRI.V2I2.344.
29. N. B. Haka, L. A. Ellyandhani, B. S. Anggoro, and A. Hamid, "Pengaruh Blended Learning Berbantukan Google Classroom terhadap Keterampilan Berpikir Kreatif dan Kemandirian Belajar Peserta Didik," *Edu Sains J. Pendidik. Sains dan Mat.*, vol. 8, no. 1, pp. 1–12, Jun. 2020, doi: 10.23971/EDS.V8I1.1806.
30. U. T. Wulanzani, U. Lestari, and I. Syamsyuri, "Hasil Validasi Buku Teks Matakuliah Bioteknologi Berbasis Bahan Alam Tanaman Pacing (Costus Speciosus Smith) sebagai Antifertilitas," *J. Pendidik. Teor. Penelitian, dan Pengemb.*, vol. 1, no. 9, pp. 1830–1835, Sep. 2016, doi: 10.17977/JP.V1I9.6837.
31. I. Addiin, T. Redjeki, and S. R. D. Ariani, "Penerapan Model Pembelajaran Project Based Learning (Pjbl) Pada Materi Pokok Larutan Asam Dan Basa Di Kelas XI IPA 1 SMA Negeri 2 Karanganyar Tahun Ajaran 2013/2014," *J. Pendidik. Kim. Univ. Sebel. Maret*, vol. 3, no. 4, pp. 7–16, 2014, Accessed: Sep. 20, 2022. [Online]. Available: https://www.neliti.com/id/publications/126193/
32. N. A. Sofyan, H. L, and A. R. Saleh, "Keefektifan Penerapan Model Pembelajaran Berbasis Proyek Terhadap Kemampuan Pemecahan Masalah Peserta Didik Pada Materi Bioteknologi," *J. Nalar Pendidik.*, vol. 6, no. 1, p. 14, 2018, doi: 10.26858/jnp.v6i1.6038.
33. S. Bell, "Project-Based Learning for the 21st Century: Skills for the Future," *undefined*, vol. 83, no. 2, pp. 39–43, Jan. 2010, doi: 10.1080/00098650903505415.
34. P. R. Sari, P. Parno, and S. Sugiyanto, "The Development of Scientific Teaching Materials Based on Stem-Pjbl as a Chance to Improve Student's Creative Thinking Ability on the Topic of Analyzing of Light and Optics," *J. Pembelajaran Sains*, vol. 5, no. 1, pp. 12–17, Apr. 2021, doi: 10.17977/UM033V5I1P.
35. R. Annisa, M. H. E. Hsb, and M. Damris, "Peningkatan Kemampuan Berpikir Kreatif Siswa dengan Menggunakan Model Project Based Learning Berbasis STEAM (Science, Technology, Engineering, Arts dan Mathematics) pada Materi Asam dan Basa di SMAN 11 Kota Jambi," *J. Indones. Soc. Integr. Chem.*, vol. 10, no. 2, pp. 42–46, 2018.
36. I. D. Astuti, Toto, and L. Yulisma, "Model Project Based Learning (PjBL) Terintegrasi STEM untuk Meningkatkan Penguasaan Konsep dan Aktivitas," *Quagga J. Pendidik. dan Biol.*, vol. 11, no. 2, pp. 93–98, Jul. 2019, doi: 10.25134/QUAGGA.V11I2.1915.
37. H. Fatmah, "Kreativitas Peserta Didik dalam Pembelajaran Bioteknologi dengan PjBL Berbasis STEAM," *Pedago. J. Ilm. Pendidik.*, vol. 5, no. 1, pp. 7–14, 2021.
38. V. Kapila and M. Iskander, "Lessons Learned from Conducting a K-12 Project to Revitalize Achievement by using Instrumentation in Science Education," *J. STEM Educ. Innov. Res.*, vol. 15, no. 1, Apr. 2014, Accessed: May 07, 2023. [Online]. Available: https://www.jstem.org/jstem/index.php/JSTEM/article/view/1760

39. T. Mayasari, A. Kadarohman, D. Rusdiana, and I. Kaniawati, "Exploration of student's creativity by integrating STEM knowledge into creative products," *AIP Conf. Proc.*, vol. 1708, no. 1, Feb. 2016, doi: 10.1063/1.4941191/884106.
40. I. K. Sudiatmika, "Penerapan Model Pembelajaran Project Based Learningdengan Pendekatan Stem Dalam Upaya Meningkatkan Hasilbelajar Fisika Peserta Didik Kelas X Rpl 1 Smk N 1 Negaratahun Pelajaran 20192020," *Widyadari J. Pendidik.*, vol. 21, no. 1, pp. 34–44, 2020, doi: 10.5281/zenodo.3742505.
41. W. Sumarni, N. Wijayati, and S. Supanti, "Kemampuan Kognitif dan Berpikir Kreatif Siswa melalui Pembelajaran Berbasis Proyek Berpendekatan STEM.," *J-PEK (Jurnal Pembelajaran Kim.*, vol. 4, no. 1, pp. 18–30, Jun. 2019, doi: 10.17977/UM026V4I12019P018.
42. M. Amri, M. S. Amri, D. A. Sudjimat, and D. Nurhadi, "Mengkombinasikan Project-Based Learning dengan STEM untuk Meningkatkan Hasil Belajar Teknikal dan Karakter Kerja Siswa SMK," *Teknol. dan Kejuru. J. Teknol. Kejuruan, dan Pengajarannya*, vol. 43, no. 1, pp. 41–50, Oct. 2020, doi: 10.17977/um031v43i12020p41-50.
43. A. Aziz and S. Subyanto, "Penerapan Penilaian Autentik Kurikulum 2013 Pada Domain Sikap Untuk Mata Pelajaran Pai Dan Budi Pekerti Di Sma Negeri 1 Asembagus," *Edupedia J. Stud. Pendidik. dan Pedagog. Islam*, vol. 3, no. 2, pp. 164–170, Jan. 2019, doi: 10.35316/EDUPEDIA.V3I2.252.
44. R. E. Bennett, "Formative assessment: a critical review," *https://doi.org/10.1080/0969594X.2010.513678*, vol. 18, no. 1, pp. 5–25, Feb. 2011, doi: 10.1080/0969594X.2010.513678.
45. S. D. Lukitawanti, Parno, and S. Kusairi, "Pengaruh PjBL-STEM Disertai Asesmen Formatif terhadap Kemampuan Pemecahan Masalah pada Materi Elastisitas dan Hukum Hooke," *J. Ris. Pendidik. Fis.*, vol. 5, no. 2, pp. 83–91, 2020.
46. J. W. Best and J. V. Kahn, *Research in Education*, 10th Editi. Cape Town: Pearson Education Inc., 2006.
47. T. D. Hastjarjo, "Rancangan Eksperimen-Kuasi," *Bul. Psikol.*, vol. 27, no. 2, pp. 187–203, Dec. 2019, doi: 10.22146/BULETINPSIKOLOGI.38619.
48. E. Silfiyah, Parno, I. J. Fitriyah, and E. Hamimi, "Pengembangan E-Modul Berbasis Project Based Learning-STEM dengan Asesmen Formatif untuk Meningkatkan Keterampilan Berpikir Kreatif pada Materi Bioteknologi," Universitas Negeri Malang, 2021.
49. R. M. Capraro, M. M. Capraro, and J. R. Morgan, *STEM Project-Based Learning An Integrated Science, Technology, Engineering and Mathematics (STEM) Approach*, Second. Rotterdam: Sense Publisher, 2013.
50. C. Andersson and T. Palm, "The Impact of Formative Assessment on Student Achievement: A Study of The Effects of Changes to Classroom Practice After a Comprehensive Professional Development Programme," *Learn. Instr.*, vol. 49, pp. 92–102, 2017, doi: 10.1016/j.learninstruc.2016.12.006.
51. C. Andersson and T. Palm, "Characteristics of Improved Formative Assessment Practice," *Educ. Inq.*, vol. 8, no. 2, pp. 104–122, 2017, doi: 10.1080/20004508.2016.1275185.
52. S. Nurjan, "Pengembangan Berpikir Kreatif," *Al-Asasiyya J. Basic Educ.*, vol. 3, no. 1, pp. 105–116, 2018.
53. Riduwan, *Dasar-Dasar Statistika*. Bandung: Alfabeta, 2014.
54. Sugiyono, *Metode PENELITIAN PENDIDIKAN (Kuantitatif,Kualitatif, dan R&D)*. Bandung: Alfabeta, 2017.
55. K. D. Kristiani, T. Mayasari, and E. Kurniadi, "Pengaruh pembelajaran STEM-PjBL terhadap keterampilan berpikir kreatif," *Semin. Nas. Pendidik. Fis.*, vol. 0, no. 0, pp. 266–274, Aug. 2017, Accessed: Apr. 10, 2023. [Online]. Available: http://e-journal.unipma.ac.id/index.php/snpf/article/view/1719

56. S. J. Lou, Y. C. Chou, R. C. Shih, and C. C. Chung, "A Study of Creativity in CaC2 Steamship-derived STEM Project-based Learning," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 13, no. 6, pp. 2387–2404, Jun. 2017, doi: 10.12973/EURASIA.2017.01231A.
57. S. D. Lukitawanti, Parno, and S. Kusairi, "Pengaruh PjBL-STEM Disertai Asesmen Formatif terhadap Kemampuan Pemecahan Masalah pada Materi Elastisitas dan Hukum Hooke," *J. Ris. Pendidik. Fis.*, vol. 5, no. 2, pp. 83–91, Nov. 2020, Accessed: Apr. 10, 2023. [Online]. Available: http://journal2.um.ac.id/index.php/jrpf/article/view/12987
58. M. E. Arce, J. L. Miguez, E. Granada, C. Miguez, and A. Cacabelos, "Project Based Learning: Application to A Research Master Subject of Thermal Engineering," *J. Technol. Sci. Educ.*, vol. 3, no. 3, pp. 132–138, Oct. 2013, doi: 10.3926/JOTSE.81.
59. N. Erdogan, B. Navruz, R. Younes, and R. M. Capraro, "Viewing How STEM Project-Based Learning Influences Students' Science Achievement Through the Implementation Lens: A Latent Growth Modeling," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 12, no. 8, pp. 2139–2154, Jul. 2016, doi: 10.12973/EURASIA.2016.1294A.
60. R. M. Capraro and M. S. Corlu, *STEM Project-Based Learning: An Integrated Science, Technology, Engineering, and Mathematics (STEM) Approach, Second Edition*. Rotterdam: Sense Publishers, 2013. doi: 10.1007/978-94-6209-143-6_12/COVER.
61. U. Munandar, *Pengembangan Kreativitas Anak Berbakat*. Jakarta: PT. Rineka Cipta, 2004.
62. Y. Buntat and N. S. Mat Nasir, "Faktor-Faktor yang Mendorong Kreativiti di Kalangan Pelajar, Universiti Teknologi Malaysia," 2011.
63. H. M. Firdaus, A. Widodo, and D. Rochintaniawati, "Analisis Kemampuan Berpikir Kreatif dan Proses Pengembangan Kemampuan Berpikir Kreatif Siswa SMP pada Pembelajaran Biologi," *Assim. Indones. J. Biol. Educ.*, vol. 1, no. 1, pp. 21–28, 2018, doi: 10.17509/aijbe.v1i1.11452.
64. L. Herlina, "Analisis Kemampuan Berpikir Kreatif Siswa Pada Materi Virus Kelas X Mas Al-Mustaqim Sungai Raya 2," *J. Bioeducation*, vol. 4, no. 2, Sep. 2017, doi: 10.29406/663.
65. R. Ningrum, T. Rahman, and R. Riandi, "Penerapan STEM FROM HOME dengan Model PjBL untuk Meningkatkan Penguasaan Konsep dan Keterampilan Berpikir Kreatif Siswa SMP," *PENDIPA J. Sci. Educ.*, vol. 6, no. 1, pp. 299–307, 2021, doi: 10.33369/pendipa.6.1.299-307.
66. N. Fajriah and E. Asiskawati, "Kemampuan Berpikir Kreatif Siswa dalam Pembelajaran Matematika Menggunakan Pendekatan Pendidikan Matematika Realistik di SMP," *EDU-MAT J. Pendidik. Mat.*, vol. 3, no. 2, Oct. 2015, doi: 10.20527/EDUMAT.V3I2.643.
67. S. Amtiningsih, S. Dwiastuti, and D. P. Sari, "Peningkatan Kemampuan Berpikir Kreatif melalui Penerapan Guided Inquiry dipadu Brainstorming pada Materi Pencemaran Air," *Proceeding Biol. Educ. Conf. Biol. Sci. Enviromental, Learn.*, vol. 13, no. 1, pp. 868–872, Nov. 2016, Accessed: May 10, 2023. [Online]. Available: https://jurnal.uns.ac.id/prosbi/article/view/5944
68. U. Munandar, *Mengembangkan Bakat dan Kreativitas Anak Sekolah*. Jakarta: Gramedia, 1999.
69. A. O. Samura, "Kemampuan Berpikir Kritis dan Kreatif Matematis melalui Pembelajaran Berbasis Masalah," *MES J. Math. Educ. Sci.*, vol. 5, no. 1, pp. 20–28, 2019, doi: 10.30743/MES.V5I1.1934.
70. R. Asriani, A. Hakim, and S. Efwinda, "Efektivitas Model Pembelajaran Inkuiri Terbimbing untuk Meningkatkan Kemampuan Berpikir Kreatif Siswa SMA pada Materi Momentum dan Impuls," *J. Literasi Pendidik. Fis.*, vol. 2, no. 1, pp. 34–43, Apr. 2021, doi: 10.30872/JLPF.V2I1.397.
71. M. Asri and D. N. P. Permana, "Pengaruh Penerapan Model Pembelajaran Project Based Learning Terhadap Keterampilan Berpikir Kreatif Siswa Pada Materi Getaran, Gelombang Dan Bunyi Di Pondok Pesantren Anshor Al-Sunnah," *J. Nat. Sci. Learn.*, vol. 1, no. 1, pp.

54–60, Jul. 2022, Accessed: Apr. 12, 2023. [Online]. Available: https://jom.uin-suska.ac.id/index.php/JNSL/article/view/7