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Profile of Scientific Creativity Based on Project Based Learning of Physics Education Undergraduate Students: Preliminary research

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ABSTRACT

This research aims to describe the profile of scientific creativity abilities of undergraduate students in the basic physics 1 course through the application of the Project-based Learning model. The sample in this research was 50 undergraduate physics education students at Madura Islamic University taking introductory physics courses. The data obtained was analyzed quantitatively and then described. The students' scientific creativity profile was obtained by administering a scientific creativity test and a student response questionnaire using the implementation of Project Based Learning. The data was analyzed using a score calculation formula, the results were categorized into very high, high, medium and low category. After obtaining the scoring, the data is interpreted in percentage form. Meanwhile, student response questionnaire were measured using Likert scale and then interpreted in percentage form. The research results showed that 83% of students' scientific creativity was still classified as low, while 17% of students' scientific creativity was classified as moderate. With details of the creative personal character profile for each indicator of scientific creativity as follows: 1) Scientific Phenomena 52.5%, 2) Scientific Knowledge 15%, 3) Scientific Problem solving 13.75%, 4) Creative thinking ability 20.4%, 5) advanced scientific product design 12.7 %, and 6) Technical product 8.7%. The results of the student response questionnaire showed that the majority of students experienced difficulty in write their initial knowledge about physics, difficulty in solving problems and answering questions based on the scientific phenomena presented.

INTRODUCTION

Science and technology have increased very rapidly over time, this will have an impact on changing life in the 21st century [1] [2]. With these changes, humans are faced with various demands of life [3] [4]. The demands of life will be able to be overcome if someone has sufficient various scientific

disciplines, broad knowledge, and skills in establishing good relationships between individuals and groups [5] [6]. Based on these needs, an education system is needed that equips students to acquire the skills needed in the 21st century [7] [8] [9]. These skills are: 1) critical thinking and problem solving; 2) Collaboration; 3) Creative and innovative; 4) Communication. These four skills are called the 4C skills [10]. According to several experts, among the skills that are very important for students to master are creative thinking and innovation, which in science is called scientific creativity [11] [12] [13] It is known that scientific creativity can help students develop systematic thinking skills, so that students are able to develop ideas and innovate in solving problems and can create products that have high value. Apart from that, with scientific creativity students can make good decisions in certain circumstances [14].

However, according to the results of the latest research conducted by Zainuddin et al [15] and the researchers themselves in 2022 and 2023, students' scientific creativity abilities are still relatively low or lacking. Not only that, the results of this research are in line with the results of the OECD report [16] [17], students' ability to think at a high level, especially in the field of science, is still relatively low, this is thought to be one of the causes is that their mastery of science is still low. is classified as low, namely at level 2 of the six existing levels. Meanwhile, to master science you must be at a minimum of level four of the six existing levels.

Scientific creativity is an indicator that someone has high level skills. According to Hu & Adey [18], scientific creativity has seven indicators, namely: 1) Understanding of Scientific phenomena, 2) science knowledge, 3) science phenomena, 4) science problems, 5) imagination, 6) Creative thinking, 7) Trait (fluency, flexibility, originality). All of these indicators are related to each other, so that people who want to master science must understand these indicators as a whole, not only that, all of these indicators of scientific creativity will guide students to think creatively and systematically so that in the end students are trained themselves to come up with ideas. Unique [14] [15] Mastering all indicators of scientific creativity through systematic thinking exercises, observing scientific phenomena, training thinking skills through creative thinking techniques including Scamper thinking techniques and listening attributes [19].

According to Kaufman [20] scientific creativity is a complex cognitive process. This is in accordance with the explanation of Belda-Medina [21] and Puente-Díaz [22] who state that learning scientific creativity which is included in the complex thinking category aims to train creative thinking so that it can give rise to new or original creative ideas. Fatonah et al [23] explained that generating creative ideas to produce an original product always involves activities that are guided by logical and systematic thinking skills. Taşdemir [24] expressed the same thing, that often a scientific phenomenon becomes a problem whose solution requires activities involving motor activity starting with scientific knowledge in the process of solving the problem with a unique idea. Therefore, in solving problems, clear creative steps are needed to make it easier for students to find solutions.

The project-based learning (PjBL) learning model has systematic learning stages. There are six stages related to scientific creativity, namely: starting learning with essential questions, creating a project design, following the activity schedule, monitoring project progress, assessing project results, evaluating learning outcomes [25] [26]. This PjBL learning model trains students to produce innovative products [27] and its application involves complex thinking skills [28] [29]. However, the results of recent research show that students' scientific creativity in learning science is still relatively low in this learning design. This shows that high-level thinking abilities in the field of science, especially physics, are still low [23]. Apart from that, it was found that the PjBL model still does not use creative thinking techniques in training the ability to generate new ideas in a structured manner. This PjBL learning model does not yet emphasize students' mastery of initial knowledge. In fact, according to Santyasa et al [30] and Nainggolan [31], that students' mastery of initial scientific knowledge in making a product is important. This finding is also reinforced by the results of other research which states that the use of creative thinking techniques is a means for students to produce creative ideas so that students' scientific creativity becomes good [32]. Based on the facts above, it is

necessary to conduct research to determine the level of scientific creativity of students using the PjBL learning model in higher education. The aim of this research is to describe the profile of students' scientific creativity by applying the PjBL model. Scientific creativity test questions with several indicators are given to students to determine their abilities in scientific creativity. As for the test material, the researchers used basic physics course material 1 including, motion kinematics, motion dynamics, energy work, and thermodynamics. The idea of preparing questions like that has never been done in any research so it is something new in this research. It is hoped that the findings of this research can help in developing learning models to increase students' scientific creativity.

METHOD

This research is preliminary research using quantitative research methods. In this research, the researcher did not test the hypothesis but only described the results of preliminary research. The subjects in this research were 50 students from the Physics Education Undergraduate Study Program at the Islamic University of Madura; consisting of 20 male students and 30 female students who were chosen randomly. Before learning using the PjBL model was carried out, all students were asked to answer a scientific creativity test on basic physics material 1 and after learning, students were asked to fill out a student response questionnaire using the PjBL learning model.

The research instruments used to collect data include: 1) scientific creativity tests and 2) student response questionnaires to learning using the PjBL model. The scientific creativity test is designed to assess students' abilities in scientific creativity. The test instrument consists of 5 scientific creativity questions which are arranged based on indicators of scientific creativity [11] [18] namely: Scientific phenomena, science knowledge, product design ability, science problems, Creative thinking, and Technical products. The research instrument was validated by three experts in their respective fields. The validity of test questions can be determined based on the mode of all scores given by experts [33]. Apart from that, research instruments were given input to be improved first before being tested. Once declared valid, all new research instruments can be used [34].

Student answers to each question item are assessed based on a rubric for assessing student scientific creativity. The test result data is then calculated using the formula from Jua [35]. which aims to determine students' scientific creativity for each indicator with the formula:

$$X = \frac{\text{total score per indikator}}{\text{maximum score of the indikator}} \times 4 \tag{1}$$

Apart from calculating the scientific creativity indicator scores, this researcher also calculated the overall score to determine the level of mastery of scientific creativity. The research data was then analyzed descriptively. Table 1 shows the average number of student scores grouped according to the criteria [36].

Table 1. Categories of Student Scientific Creativity

| Value | Assessment criteria |
|---------------------|---------------------|
| 3,33 < score ≤ 4,00 | Very high |
| 2,00 < score ≤ 3,33 | high |
| 0,67 < score ≤ 2,00 | Moderate |
| score ≤ 0,67 | Low |

The student response questionnaire used in this research was to determine student responses to the learning process that had been carried out. Student responses to learning are then calculated and expressed as a percentage. Criteria for calculation results from questionnaires and tests adopted from Zalaf et al [37] and Abdillah [38] as in Table 2.

Table 2. Interpretation of percentage of response questionnaire scoring criteria

| Percentage (%) | Criteria |
|----------------|-----------------|
| 76 – 100 | Very agree |
| 51 – 75 | Agree |
| 26 – 50 | Deficient agree |
| 0- 25 | Don't agree |

The flow of this research is shown in Figure 1.

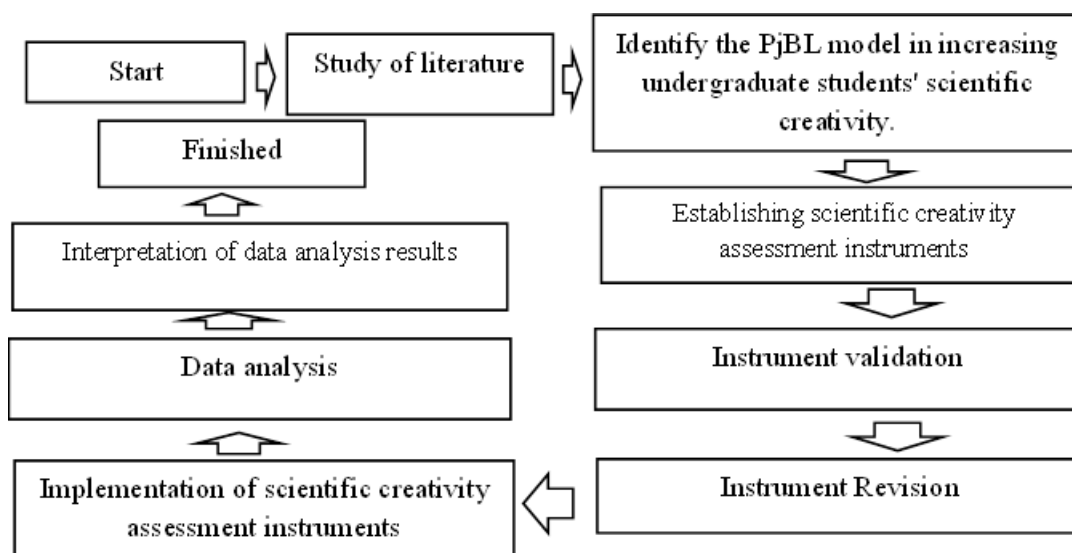


Fig 1. Research Flow

RESULTS AND DISCUSSIONS

Results

The preliminary study's results include the results of scientific creativity tests and student response questionnaires regarding the learning process using the PjBL model. Table 3 displays the results of students' scientific creativity tests.

Table 3. Results of students' scientific creativity tests in basic physics course 1

| No | Indicators of scientific creativity | Trait | | | Score | Category |
|----------------|-------------------------------------|-------------|-------------|-------------|-------------|------------------|
| | | Fluency | flexibility | Originality | | |
| 1 | Scientific Phenomena | 2,0 | | 2,2 | 2,1 | Moderate |
| 2 | Scientific knowledge | 0,80 | 0,60 | 0,40 | 0,60 | Deficient |
| 3 | Scientific problem solving | 0,60 | 0,50 | 0,55 | 0,55 | Deficient |
| 4 | Creative thinking ability | 0,80 | 0,45 | | 0,63 | Deficient |
| 5 | Advance scientific design product | 0,72 | 0,30 | 0,50 | 0,51 | Deficient |
| 6 | Technical product ability | | 0,60 | 0,40 | 0,50 | Deficient |
| Average | | 0,98 | 0,49 | 0,81 | 0,81 | Deficient |

Table 3 shows that the value of each indicator of scientific creativity is in the low and medium categories. Five indicators of scientific creativity are categorized as poor, while only one indicator is categorized as moderate. The score of creative personal character based on six indicators of scientific creativity is generally in the medium category. The scores for indicators of scientific creativity and creative personal character (*Fluency*, *Flexibility*, *Originality*), which are interpreted in percentage form, are presented in Figure 2.

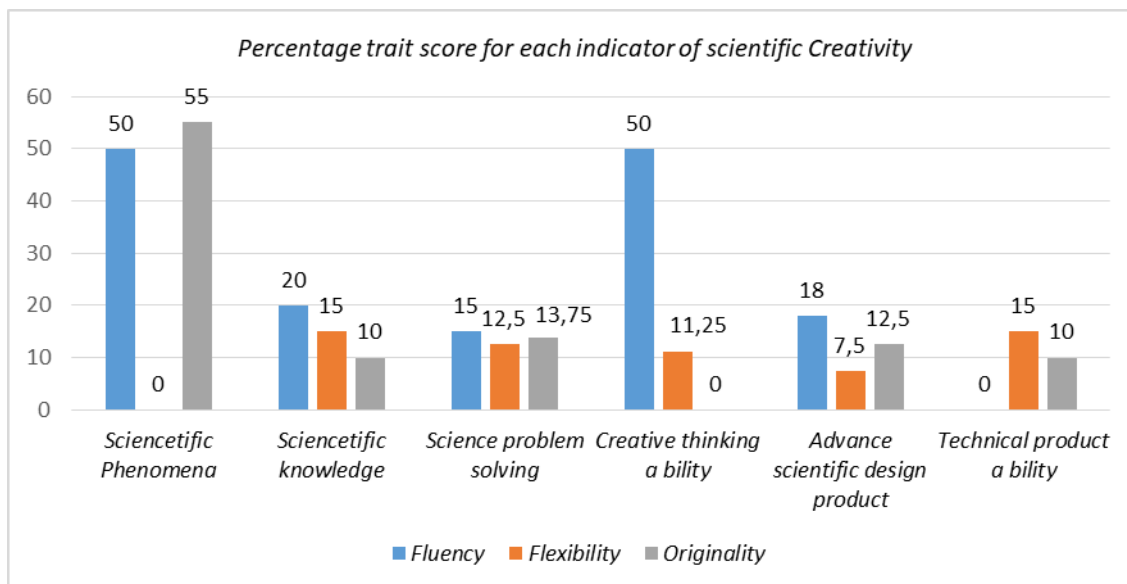


Fig 2. Percentage of creative personal characteristics for each indicator of scientific creativity

Based on Figure 2, the creative personal character for each indicator of scientific creativity achieved by Physics Education undergraduate students is generally below 50%. In the indicators of scientific creativity, scientific phenomena, and creative thinking, the personal character of creative flexibility and originality is 50-55%, while the personal character of creative flexibility and originality in all indicators of scientific creativity is less than 50%. Meanwhile, the results of the student response questionnaire are presented in Table 4.

Table 4. Results of student response questionnaires

| No | Questions | Percentage of "Yes" answers | Criteria |
|----|--|-----------------------------|------------|
| 1 | Are you able to answer the questions presented at the beginning? | 52,4% | Agree |
| 2 | Does your previous knowledge influence your answer? | 65% | Agree |
| 3 | Do you find it difficult when you are asked to write down a physics concept? | 90% | Very agree |
| 4 | Do you have difficulty when you are asked to solve a scientific problem? | 70% | Agree |
| 5 | Do you need help generating creative ideas to make a product? | 90% | Very agree |

Based on Table 4, most students experience difficulty writing physics concepts and generating creative ideas, with a percentage value of 90%. Meanwhile, 65% to 70% of students have difficulty solving problems related to scientific phenomena. Only 52.4% of students could answer questions presented in the form of scientific phenomena.

Discussions

Based on the results of the scientific creativity test in Table 3, research findings show that lecturers have practiced scientific creativity through the PjBL learning model. However, based on the results of this research, students' scientific creativity is in the low category with a percentage of 83%, and students reach the medium category with a percentage of 17%. With details of the creative personal character profile for each indicator of scientific creativity as follows: 1) Scientific Phenomena 52.5%, 2) Scientific Knowledge 15%, 3) Scientific Problem solving 13.75%, 4) Creative thinking ability 20.4%, 5) advanced scientific product design 12.7 %, 6) Technical products 8.7%. This is caused by most students having difficulty writing down knowledge about physics concepts and generating

creative ideas. The second reason is that students are not used to thinking complexly, which can be seen from the results of the creative personal character for each creativity indicator (Figure 2).

Based on the results of this research, lecturers have trained scientific creativity in undergraduate physics education students in basic physics courses using a project-based learning model. The PjBL model is designed to help students increase scientific creativity [26] [39]. However, there are still limitations in increasing students' scientific creativity; these limitations lie in one phase of the PjBL model. One of these limitations is not yet practicing mastery of initial knowledge and the ability to generate creative ideas. Prior knowledge is important in investigations, producing products, and solving problems [40]. Previously acquired experience and knowledge will enable one to adapt to different situations [40]. According to Santoso [41], the diversity of students' initial knowledge in applying the PjBL model for higher-order thinking skills can pose challenges.

The PjBL model has six phases: 1) determining basic questions, 2) preparing project plans, 3) preparing schedules, 4) monitoring, 5) testing results, and 6) evaluating experiences [25] [42] [43]. Based on the six stages of the PjBL learning model above, there is no stage to explore students' science knowledge and train creative thinking skills. These two stages are very important in increasing scientific creativity [15] [44]. This is reinforced by the opinion of Dwikoranto [14], that The PjBL learning model will encourage students to produce creative ideas in solving problems.

In this research, observing scientific phenomena indicates creativity, which most students have mastered. This can be seen from the results of students' scientific creativity tests, which were answered well. Meanwhile, the ability to think creatively in generating creative ideas is still relatively low; this can happen because solving problems requires high-level thinking skills [32] [45] [46] [47]. This is based on research conducted by Prahani [48] and Suyidno [49] which found that scientific creativity is the key to high-level thinking.

The results of the student response questionnaire listed in Table 4 are findings that strengthen the findings of the low scientific creativity test results of physics education undergraduate students. This can be seen from the students' answers, most of whom answered difficulties in solving complex problems, difficulties in writing physics material, or initial knowledge about physics with a percentage of 90%. Then, students could answer questions related to scientific phenomena with a percentage of 52.4%. Students will get used to finding solutions if they have sufficient initial knowledge to construct them with current experience [50] [51] research shows that prior knowledge is essential capital in solving project-related problems. Students' scientific creativity will develop with sufficient knowledge [52].

Based on several findings in this research, the PjBL model still has limitations in training scientific creativity in physics students at universities; therefore, model development is needed to overcome the limitations of the PjBL model. This is by Dolmans [53] statement regarding re-adapting a learning model by considering existing constraints. Apart from the existing PjBL model phases, in developing the PjBL model, you must pay attention to indicators of prior knowledge and steps for creative thinking abilities in developing the model because these two indicators help students generate creative ideas. This is the opinion of Park et al [13], Siagian et al [54], and Siew & Ambo [55], that prior knowledge is an essential aspect in training students' scientific creativity.

This research is only limited to 1) this research is only limited to the essential material of fundamental physics 1, namely motion kinematics, dynamics, energy work, and thermodynamics; 2) this research sample is only limited to 50 students at one university. Thus, it is necessary to conduct further research: 1) with different materials; 2) with a more significant number of samples in several universities.

CONCLUSION AND SUGGESTION

The conclusions in this research are: 1) the scientific creativity abilities of Physics Education Undergraduate Study Program students are still relatively low. 2) the application of the Project based learning model has not fully trained students' scientific creativity; 3) students are still unable to solve complex problems related to scientific phenomena; 4) low scientific creativity occurs in most indicators including mastery of initial knowledge and the ability to think creatively. This preliminary research has an impact on the development of the PjBL model syntax which is realized in a new learning model.

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REFERENCES

- [1] Abaniel, A. (2021). Enhanced Conceptual Understanding, 21st Century Skills and Learning Attitudes through an Open Inquiry Learning Model in Physics. *Journal of Technology and Science Education*, 11(1), 30-43.
- [2] Yurt, E. (2023). 21st-century skills as predictors of pre-service teachers' professional qualifications: A cross-sectional study. *International Journal of Education in Mathematics, Science and Technology*, 11(5), 1328-1345.
- [3] Muhali, M. (2019). Pembelajaran inovatif abad ke-21. *Jurnal Penelitian Dan Pengkajian Ilmu Pendidikan: E-Saintika*, 3(2), 25-50.
- [4] Rahayu, R., Iskandar, S., & Abidin, Y. (2022). Inovasi pembelajaran abad 21 dan penerapannya di Indonesia. *Jurnal Basicedu*, 6(2), 2099-2104.
- [5] Fung, C. H., Poon, K. K., & Ng, S. P. (2022). Fostering student teachers' 21st century skills by using flipped learning by teaching in STEM education. *Eurasia Journal of Mathematics, Science and Technology Education*, 18(12), em2204.
- [6] Muhammad, A. E. (2019). The 21st century learning as a knowledge age: The effects on teacher's transforming teacher's knowledge in technology-rich environment in social studies education. *Journal of Critical Reviews*, 7(7), 2020.
- [7] Dwivedi, V. J., & Joshi, Y. C. (2020). Leadership Pivotal to Productivity Enhancement for 21st-Century Indian Higher Education System. *International Journal of Higher Education*, 9(2), 126-143.
- [8] Hanicza, Y., Putri, D. H., & Hamdani, D. (2021). Identification of debriefing 21 st century skills on aspects of critical thinking skills and communication skills in Bengkulu high school students in physics subjects. In *Journal of Physics: Conference Series* (Vol. 1731, No. 1, p. 012069). IOP Publishing.
- [9] Wibowo, F. C. (2023). Effects of Augmented Reality Integration (ARI) Based Model Physics Independent Learning (MPIL) for Facilitating 21st-Century Skills (21-Cs). *Journal of Technology and Science Education*, 13(1), 178-192.
- [10] Yulianti, D., Sugianto, S., & Ngafidin, K. M. (2022). Scratch assisted physics learning with a STEM approach in the pandemic era to develop 21st century learning skills. *Jurnal Pendidikan IPA Indonesia*, 11(1), 185-194.
- [11] Chin, M. K., & Siew, N. M. (2015). The development and validation of a figural scientific creativity test for preschool pupils. *Creative Education*, 6(12), 1391.
- [12] Kurniawati, F., Saleh, A. Y., & Safitri, S. (2022). How to foster students' creativity? The effects of teacher subjective well-being mediation on the intellectual humility. *Cakrawala Pendidikan: Jurnal Ilmiah Pendidikan*, 41(1), 31-42.

- [13] Park, J., Yoon, H. G., & Lee, I. (2023). Based Teaching: Analyzing Science Teachers' Process of Understanding and Using Academic Papers to Teach Scientific Creativity. *Journal of Baltic Science Education*, 22(1), 57-72.
- [14] Jatmiko, B., Hariyono, E., Lestari, N. A., & Prahani, B. K. (2021, March). MobLen Model for Enhancing Scientific Creativity of Physics Students: An Alternative in the Covid-19 Pandemic. In *Journal of Physics: Conference Series* (Vol. 1805, No. 1, p. 012006). IOP Publishing.
- [15] Dewantara, D., Mahtari, S., Nur, M., Yuanita, L., & Sunarti, T. (2020). The Correlation of Scientific Knowledge-Science Process Skills and Scientific Creativity in Creative Responsibility Based Learning. *International Journal of Instruction*, 13(3), 307-316.
- [16] *PISA 2022 Results (Volume I and II) - Country Notes: Indonesia / OECD*. (n.d.).
- [17] Suprayitno, T. (2019). Pendidikan di Indonesia: belajar dari hasil PISA 2018.
- [18] Hu, W., & Adey, P. (2002). A scientific creativity test for secondary school students. *International Journal of Science Education*, 24(4), 389-403.
- [19] Altıparmak, T., & Eryılmaz-Mustu, Ö. (2021). The Effects of SCAMPER Technique Activities in the 8th Grade Simple Machines Unit on Students' Academic Achievement, Motivation and Attitude towards Science Lessons. *International Journal of Educational Methodology*, 7(1), 155-170.
- [20] Hu, W., Wu, B., Jia, X., Yi, X., Duan, C., Meyer, W., & Kaufman, J. C. (2013). Increasing students' scientific creativity: The "learn to think" intervention program. *The journal of creative behavior*, 47(1), 3-21.
- [21] Belda-Medina, J. (2022). Promoting inclusiveness, creativity and critical thinking through digital storytelling among EFL teacher candidates. *International Journal of Inclusive Education*, 26(2), 109-123.
- [22] Puente-Díaz, R. (2023). Metacognitive feelings as a source of information for the creative process: A conceptual exploration. *Journal of Intelligence*, 11(3), 49.
- [23] Fatonah, S., Prasetyo, Z. K., Utami, A. D., Chasanah, U., Lusiana, L., & Siregar, V. V. (2024). Scientific Attitude and Its Effect on Students' Productivity. *Jurnal Pendidikan IPA Indonesia*, 12(4).
- [24] Taşdemir, C. Y. (2021). Is Scientific Creativity Possible in Early Childhood?. *Theory and Practice in Child Development*, 1(1), 71-82.
- [25] Ismuwardani, Z., Nuryatin, A., & Doyin, M. (2019). Implementation of project based learning model to increased creativity and self-reliance of students on poetry writing skills. *Journal of Primary Education*, 8(1), 51-58.
- [26] Wijayati, N., Sumarni, W., & Supanti, S. (2019). Improving student creative thinking skills through project based learning. *KnE Social Sciences*, 408-421.
- [27] Prajoko, S., Sukmawati, I., Maris, A. F., & Wulanjani, A. N. (2023). Project based learning (pjb) model with stem approach on students' conceptual understanding and creativity. *Jurnal Pendidikan IPA Indonesia*, 12(3), 401-409.
- [28] Arzak, K. A., & Prahani, B. K. (2023). Practicality of Augmented Reality Books in Physics Learning: A Literature Review. *JPPS (Jurnal Penelitian Pendidikan Sains)*, 12(2), 138-154.
- [29] Prahani, B. K., Suprpto, N., Rachmadiarti, F., Sholahuddin, A., Mahtari, S., & Siswanto, J. (2021). Online Scientific Creativity Learning (OSCL) in Science Education to Improve Students' Scientific Creativity in COVID-19 Pandemic. *Journal of Turkish Science Education*, 18, 77-90.
- [30] Santyasa, I. W., Rapi, N. K., & Sara, I. (2020). Project based learning and academic procrastination of students in learning physics. *International Journal of instruction*, 13(1), 489-508.
- [31] Nainggolan, B., Hutabarat, W., Situmorang, M., & Sitorus, M. (2020). Developing Innovative Chemistry Laboratory Workbook Integrated with Project-Based Learning and Character-Based Chemistry. *International Journal of Instruction*, 13(3), 895-908.
- [32] Khoiri, N., Ristanto, S., & Kurniawan, A. F. (2023). Project-based learning via traditional game in physics learning: Its impact on critical thinking, creative thinking, and collaborative skills. *Jurnal Pendidikan IPA Indonesia*, 12(2), 286-292.
- [33] Siagan, M. V., Saragih, S., & Sinaga, B. (2019). Development of Learning Materials Oriented on Problem-Based Learning Model to Improve Students' Mathematical Problem Solving Ability and

- Metacognition Ability. *International electronic journal of mathematics education*, 14(2), 331-340.
- [34] Bars, M. (2022). Adaptation of Metacognition in Mathematics Scale to Turkish: A Validity and Reliability Study. *International Online Journal of Educational Sciences*, 14(3).
- [35] Jua, S. K. (2018, May). The profile of students' problem-solving skill in physics across interest program in the secondary school. In *Journal of Physics: Conference Series* (Vol. 1022, No. 1, p. 012027). IOP Publishing.
- [36] Borich, G. D. (1974). *An Evaluation of the Personalized Model of Teacher Training*. Final Report.
- [37] Zalut, M. M., Hamed, M. S., & Bolbol, S. A. (2021). The experiences, challenges, and acceptance of e-learning as a tool for teaching during the COVID-19 pandemic among university medical staff. *PloS one*, 16(3), e0248758.
- [38] Napitupulu, D., Simarmata, J., Abdillah, L. A., Setiawan, M. I., Ahmar, A. S., Rahim, R., ... & Erliana, C. I. (2017, November). Analysis of technology acceptance model (TAM) on e-learning system. In *2017 International Conference on Education and Technology (2017 ICEduTech)* (pp. 247-251). Atlantis Press.
- [39] Sumo, M., Jatmiko, B., Supardi, Z. A. I., & Suprianto, S. (2024). The Influence Of The Project-Based Learning Model On The Scientific Creativity Of Physics Education Undergraduate Students At Madura Islamic University. *SEJ (Science Education Journal)*, 8(1), 19-31.
- [40] Arends, R. (2004). *Guide to Field Experiences and Portfolio Development to Accompany Learning to Teach, Sixth Edition* (Vol. 2). McGraw-Hill.
- [41] Santoso, A. M., Primandiri, P. R., Zubaidah, S., & Amin, M. (2021, March). The development of students' worksheets using project based learning (PjBL) in improving higher order thinking skills (HOTS) and time management skills of students. In *Journal of Physics: Conference Series* (Vol. 1806, No. 1, p. 012173). IOP Publishing.
- [42] Nizam, N., & Partiw, S. G. (2023). *Panduan Implementasi Pembelajaran Berpusat Pada Mahasiswa*.
- [43] Wahyuni, L., & Rahayu, Y. S. (2021). Pengembangan e-book berbasis project based learning (pjbl) untuk melatih kemampuan berpikir kreatif pada materi pertumbuhan dan perkembangan tumbuhan kelas xii sma. *Berkala Ilmiah Pendidikan Biologi (BioEdu)*, 10(2), 314-325.
- [44] de Vries, H. B., & Lubart, T. I. (2019). Scientific creativity: divergent and convergent thinking and the impact of culture. *The Journal of Creative Behavior*, 53(2), 145-155.
- [45] Ananda, L. R., Rahmawati, Y., & Khairi, F. (2023). Critical Thinking Skills of Chemistry Students by Integrating Design Thinking with STEAM-PjBL. *Journal of Technology and Science Education*, 13(1), 352-367.
- [46] Kusumaningtyas, D. I. (2022). Keterampilan abad 21 dalam model-model pembelajaran berpendekatan STEAM pada RPP tematik SD. *JRPD (Jurnal Riset Pendidikan Dasar)*, 5(1), 74-81.
- [47] Suradika, A., Dewi, H. I., & Nasution, M. I. (2023). Project-based learning and problem-based learning models in critical and creative students. *Jurnal Pendidikan IPA Indonesia*, 12(1), 153-167.
- [48] Prahani, B. K., Susiawati, E., Deta, U. A., Lestari, N. A., Yantidewi, M., Jauhariyah, M. N. R., ... & Siswanto, J. (2021, February). Profile of students' physics problem-solving skills and the implementation of inquiry (free, guided, and structured) learning in senior high school. In *Journal of Physics: Conference Series* (Vol. 1747, No. 1, p. 012012). IOP Publishing.
- [49] Nur, M., Yuanita, L., Prahani, B. K., & Jatmiko, B. (2018). Effectiveness of Creative Responsibility Based Teaching (CRBT) Model on Basic Physics Learning to Increase Student's Scientific Creativity and Responsibility. *Journal of Baltic Science Education*, 17(1), 136-151.
- [50] Moreno, F. E., & Díaz, M. R. (2021, October). Learning electrical circuits for the development of critical thinking. In *Journal of Physics: Conference Series* (Vol. 2073, No. 1, p. 012001). IOP Publishing.
- [51] Setemen, K., Sudirtha, I. G., & Widiana, I. W. (2023). The Effectiveness of Study, Explore, Implement, Evaluate E-Learning Model Based on Project-Based Learning on the Students Conceptual Understanding and Learning Agility. *Journal of Technology and Science Education*, 13(3), 583-596.

- [52] Putri, S. U., Sumiati, T., & Larasati, I. (2019, February). Improving creative thinking skill through project-based-learning in science for primary school. In *Journal of Physics: Conference Series* (Vol. 1157, No. 2, p. 022052). IOP Publishing.
- [53] Dolmans, D. H. (2019). How theory and design-based research can mature PBL practice and research. *Advances in health sciences education*, 24(5), 879-891.
- [54] Siagian, A. F., Ibrahim, M., & Supardi, Z. A. I. (2023). Creative-scientific decision-making skills learning model for training creative thinking skills and student decision making skills. *Nurture*, 17(1), 10-17.
- [55] Siew, N. M., & Ambo, N. (2020). The Scientific Creativity of Fifth Graders in a STEM Project-Based Cooperative Learning Approach. *Problems of Education in the 21st Century*, 78(4), 627-643.