Jurnal Pendidikan Sains Universitas Muhammadiyah Semarang. Vol. 12(1) pp 40-51 ISSN:2339-0786
DOI: https://doi.org/10.26714/jps.12.1.2024.40-51

JPS JOURNAL PENDIDIKAN SAINS | JURNAL PENDIDIKAN SAINS UNIVERSITAS MUHAMMADIYAH SEMARANG
p-ISSN : 2339-0786 o-ISSN : 2502-1443

Fostering Students' Attitudes Towards STEM Using STEM Project-Based Learning in Learning Optical Instruments

Adinda Zaskia Yasmin Muntaz [a,1], Nanang Winarno[b,2*] , Rizki Maulana Ashidiq [c,3], Sujito[d,4]

[a,b,c] Department of Science Education, Universitas Pendidikan Indonesia, Bandung, 40154, Indonesia
[c] Graduate Institute of Science Education, National Taiwan Normal University, Taipei, 10607, Taiwan
[d] Department of Physics, Universitas Negeri Malang, Malang, 65145, Indonesia

[1]adindazaskia@upi.edu; [2]nanang_winarno@upi.edu; [3]rizki.ashidia@upi.edu; [4]sujito.fmipa@um.ac.id
* corresponding author

Article history

Submission : 2024-03-03
Revised : 2024-03-03
Accepted : 2023-10-06

Keyword

STEM-PJBL
Attitudes towards STEM
Engineering and Technology
Science
Mathematics

Abstract

Education is a key driver in cultivating a skilled generation, providing innovative STEM learning to enhance prospects. This research analyzed the effect of STEM project-based Learning in optical instrument topics on students' attitudes and perceptions toward STEM. Conducted through a quasi-experimental method, the research drew its sample from 8th-grade students in a junior high school in Bandung, Indonesia, evenly split between control (n=30) and experimental (n=30) classes. The control class is taught by project-based learning, while STEM PJBL is taught to the experimental class. The result of this study was an N-Gain of students' attitudes towards STEM in experimental class showed a 0.11, which is still categorized as low enhancement. The T-test result (asymp. sig. (2-tailed) = 0.54) also shows no significant difference between the control and experimental classes. Furthermore, engineering and technology are favored by the STEM subscale, seen as fostering creativity subscale, followed by science, which students enjoy most of the science with no counting lessons, However, most students hold a negative view of the mathematics subscale due to the complexity of formulas provided in the lesson. Based on this research, STEM-PJBL should be applied in creative, innovative, and consistent ways within the science class to get a higher shift in students' attitudes.

1. INTRODUCTION

The rapid development of science and engineering in the 21st century reshapes industries and continuously drives innovation. The job market is profoundly transforming, necessitating new skills and competencies to thrive in the modern workforce. Employers increasingly seek individuals equipped with 21st-century science, technology, engineering, and mathematics (STEM) skills, encompassing knowledge, critical thinking, and collaboration. The evolving job market demands these specific skill sets to meet the challenges and opportunities presented by the advancements of this century (Zhou et al., 2019). Education is one of the motors that creates a highly skilled generation by developing new approaches. As the world's new educational trend, STEM, which consists of the initials of Science, Technology, Engineering, and Mathematics, is an educational approach that aims to help individuals gain information and skills through an interdisciplinary approach. Another aim of STEM is to raise individuals who can handle the economic power that can offer an advantage in the industrialization of countries and to transform countries into economically and industrially developed countries (Çevik & Özgünay 2018). STEM education aims to advance future generations with an innovative approach (Çorlu, Capraro, & Capraro, 2014).

Unfortunately, the increasing need for STEM skills is not accompanied by student involvement in STEM itself. Several nations, such as the United States and various European countries, are presently confronted with the issue of declining interest among students in STEM-related subjects (Osborne & Dillon, 2008). Many secondary and post-secondary students are opting to switch from STEM majors to other disciplines. Moreover, although many secondary school students excel in mathematics, they do not pursue STEM majors in college. Additionally, only half of the students who initially chose STEM majors completed their STEM degrees (Carnevale et al., 2011). In Indonesia, compared to Senior High School (SHS) students, Junior High School (JHS) students have less experience in STEM learning. Although a small percentage of them had studied STEM, they did not show a positive impression toward STEM learning, even 4 out of 20 JHS students said they were tired of STEM learning (Permanasari et al., 2021).

As one of the disciplines that play a vital role in technological growth, physics is viewed as both a process and a result, so in learning (Azhar, 2008), effective and efficient learning techniques or approaches must be considered (Aripin et al., 2021). However, present school-based learning is still student-centered (Syahfira et al., 2021) and geared at measuring students' memory, making learning physics less appealing to pupils (Dewi & Primayana, 2019). Light and optical instrument topics are fundamental competencies covered in a science course. Besides that, previous studies revealed that light and optical instruments are difficult and challenging topics among students, often leading to misconceptions (Galili & Hazan, 2000; Ling, 2017.

To address this issue, the researchers proposed a solution within an integrated STEM project-based learning approach in the light and optics chapter for 8th-grade junior high school students. The study by Tseng et al. (2013) found that students' attitudes to engineering changed significantly after completing STEM-integrated project-based learning. Several supporting studies stated that STEM PjBL improves students' self-efficacy in solving physics problems (Samsudin et al., 2020). As evident from the comparison between the pre-test and post-test, the Project-based Integrated STEM Program positively affected student attitudes toward STEM (Zhou et al., 2019). Engaging in at least one project-based course during the first four semesters affected student perceptions of STEM skills, the utility value of participating in STEM courses, and STEM career aspirations (Bier et al., 2019). A meaningful difference was found in students' attitudes towards STEM before and after the application in the experimental group provided with STEM practices. This finding suggests that STEM practices integrated into a science course effectively improve students' attitudes toward STEM (Kurt & Benzer, 2020). The STEM-integrated robotics curriculum caused students to gain more positive attitudes toward math (Ching et al., 2019). A STEM project using 3D printing with repetitive modeling effectively developed high school student's interest in technology and engineering careers (Lin et al., 2021). PBL interventions foster learning of science and technology concepts, as well as encourage positive attitudes toward STEM (Hasni et al., 2016). The present study supports the positive impact of a PBL experience on students' attitudes toward STEM and suggests that this type of intervention can be a powerful tool to encourage students to view science as a useful tool for their professional development (Escobar & Qazi, 2020).

Besides STEM-integrated project-based learning can increase attitudes towards science, several studies say that the application of PJBL stem has a positive effect on several aspects, such as students' computational thinking skills and their perception of Stem skill levels (Karaahmetoğlu & Korkmaz, 2019), enhance students' scientific and environmental literacy (Afriana et al., 2016; Winarni et al., 2022), improve 21st-century skill such as critical thinking, collaborative skill, creative thinking, and scientific creativity (Lou et al., 2017; Siew & Ambo, 2018; Hanif et al., 2019; Sumarni & Kadarwati, 2020; Bulu & Tanggur, 2021). Hence, the integration of STEM and project-based learning can be methods that can be considered to be implemented in science learning to create graduates who can compete and fill expert benches in the industrial era 4.0 with all the optimization of the use of technology.

The previous studies are about how STEM-integrated project-based learning affects students' attitudes toward science research in Taiwanese freshmen and high school and elementary school students (Tseng et al., 2013; Lin, et al., 2021; Zhou et al., 2019), Malaysian 10th-grade high school students (Samsudin et al., 2020), American primary school, high school, and university students (Ching et al., 2019; Bier et al., 2019; Escobar & Qazi, 2020). Turkish 6th-grade high school students (Kurt & Benzer, 2020). However, this study aims to analyze the effect of STEM project-based learning in Indonesian junior high school students in grade 8.

Earlier research related to this field provided on different topics, such as global health and bioscience (Bier et al., 2019), electric vehicles (Tseng et al., 2020), vibration isolator (Lin et al., 2021), gears, energy, and an electromagnet (Zhou, et. al, 2019), pulley (Samsudin et al., 2020), robotics (Ching, et. al, 2019), alternative energy (Escobar & Qazi, 2020), and electrical circuit (Kurt & Benzer, 2020). Reviewing those previous studies, only a few studies explain the effect of STEM PJBL related to optical instrument learning, so our study presents a novelty to reveal the effect of STEM PJBL in learning optical instruments.

According to the background stated the research questions of this study are:

1. How does the effect of STEM Project-Based Learning on students' attitudes towards STEM in learning optical instruments?
2. How do students' perceptions towards science, technology, engineering, and mathematics?

2. METHOD

Research Design

The Quasi-experimental was employed as the research approach in this study. The research design in this study was a pre-test and post-test control group design (Cresswell, 2014). The researcher divided the individuals into two groups. The researcher specified one group as the experimental group and the other as the control group then administered a pre-test for both groups, conducted experimental treatment activities on the experimental group only, and then provided a post-test to compare the two groups. The scheme of experimental design can be seen in Table 1.

Table. 1. Quasi-experimental design

	O_1	Treatment	O_2
Control Group	Pre-test	Project Based Learning (C)	Post-test
Experiment Group	Pre-test	STEM Project Based Learning (X)	Post-test

Source: (Cresswell, 2014)

Participants

The participants involved in this study are male students in grade 8 of Junior High Islamic Boarding School Bandung, Indonesia. In a total of 60 students, there were 30 students for the experiment class and 30 for the control class. Participants have a range of ages between 13-15 years old. The sampling technique utilized in this study is purposive sampling, also known as judgment sampling, which is the deliberate selection of a participant based on the traits the subject possesses. It is a nonrandom approach that does not require underlying theories or a predetermined number of participants (Etikan et al., 2016).

Research Instrument

The instrument used for measuring students' attitudes towards STEM is the S-STEM Survey developed by Unfriend et al. (2015). The S-STEM questionnaire had 37 5-point Likert-type items (strongly agree to strongly disagree). 26 statements will evaluate students' STEM attitudes, with 8 items (Q1-Q8) focusing on Mathematics, 9 items (Q9-Q17) on science, and 9 items (Q18-Q26) on Engineering/Technology. The rest of the 11 items in the questionnaire (Q27-37) are labeled as the 21st century skills subscale. This study adapted only 26 statements from 3 parts, Mathematics, Science, and Engineering/Technology, and translated them into Indonesian. The researcher also developed an additional 4 open-ended questions to elaborate on students' perceptions of mathematics, science, and engineering/technology.

Cronbach's alpha was used to assess internal consistency reliability for the four constructs. For each survey, these values were obtained using the whole sample of data. All constructs indicated adequate levels of reliability for the Middle/High S-STEM Survey in the value of 0.89-0.92 (Unfriend et al, 2015).

Data analysis

The raw data is checked for distribution first to analyze the study's major research question. If it is normally distributed, then the independent sample t-test is performed. Independent samples t-test is used to contrast two groups whose means are unrelated (Gerald, 2018). If the data do not meet the parametric assumptions of the t-test, the Mann-Whitney U tends to be more appropriate (McKnight and Najab, 2010). Elaboration of the N-Gain test was also performed to discover the comparison of mean scores between experimental and control groups. The categorization of the N-Gain score can be seen in Table 2.

Table 2. Categories of N-Gain

N-Gain	Interpretation
$g > 0.70$	High
$0.70 < g \leq 0.30$	Moderate
$g \leq 0.30$	Low

(Meltzer, 2002)

Research Procedure

This study utilizes quasi-experimental use, matching only the pretest and posttest control group designs. It uses 3 stages which are the deciding stage, the implementing stage, and the evaluation stage. The detailed activities of implementation excluded pre-test and post-test in the classroom shown in Table 3.

Table. 3. Activities in Control and Experimental Class

Experiment Class		Control Class	
STEM Project-Based Learning Stages	Activities	Project-Based Learning Stages	Activities
1. The stage of preparation	Students create a group. Students recognize the project idea and scope of optical devices and handcrafted projectors. Students learn about the fundamental principle of creating a homemade projector through the internet and scientific literature.	1. Formulation of group project plans	Students form a group. Students recognize the project concept and scope of optical devices and handcrafted projectors. Students obtain information about the basic principles of creating handmade projectors from books on the internet.
2. The stage of implementation	Based on the group discussion, students create a self-made projector design. Students outline the tools and supplies that will be utilized. Students create the project using the design sketch.	2. Applying the project	Based on the group discussion, students create a self-made projector design. Students outline the tools and supplies that will be utilized. Students create the project using the design sketch
3. The stage of presentation	Students perform a real test of their product, which includes calculating the focal length of the lens,	3. Planning the presentation	Students perform a real test of their product, which includes calculating the focal length of the lens,

	discussing the picture creation characteristics, and drawing conclusions. Each group presents their product and the philosophy behind it.		discussing the picture creation characteristics, and drawing conclusions.
4. The stage of evaluation	Students do peer reviews on the output of another group. The teacher evaluates the product of the students.	4. The presentation	Each group presents their product and the philosophy behind it.
5. The stage of correction	Students self-correct the product in response to suggestions and criticism. Furthermore, students begin to update the self-made projector in response to suggestions.	5. The Evaluation	The teacher evaluates the product of the students.

(Bilgin et al, 2015; Lou et al, 2017)

3. RESULTS AND DISCUSSION

Effect of STEM Project-Based Learning on Students' Attitude Towards STEM

Research question number 1 can be answered by conducting statistical tests to see whether there's a significant difference between the control and experimental classes. Before running the statistical test, a normality test using the Shapiro-Wilk method was taken because the samples were less than 50 (Razali and Wah, 2011). The provision of the Shapiro-Wilk test is if the sig. of both groups > 0.05 then the data is normally distributed (Rahardjo, 2015). The result of the normality test can be seen in Table 4.

Table 4. Normality Test

Condition	Classes	Sig.
Pre Test	Control	.013
	Experiment	.115
Post Test	Control	.014
	Experiment	.053
Conclusion	Not normally distributed	

The test result showed that the data are not normally distributed, so the test that should be used to analyze the significance difference between the groups is the Mann-Whitney test or nonparametric t-test. The value of Asymp. Sig. (2-tailed) indicating the significant difference between the control and experimental class if the value is < 0.05 (Rahardjo, 2017). Hence in the current study, there's no significant difference in students' attitudes toward STEM in the pre-test and post-test for both the control and experimental classes. Non-parametric t-test results can be seen in Table 5.

Table 5. Nonparametric T-Test Result

Grouping Variable	Condition	Asymp. Sig. (2-tailed)
Experiment and Control Class	Pre Test	.203
	Post Test	.540

The mean score of the pre-test and post-test for both control and experiment classes was also studied and achieved more than 3.00, which indicates a positive attitude on the whole S-STEM test (Zhou et al., 2019). There's an increasing mean point in both groups despite the increase points being less than 0 (Control class: 0.04; Experimental class: 0.2). The result of the mean comparison for the control and experiment class can be seen in Table 6.

Table 6. Mean Comparison between Control and Experiment Class

Class	Mean Pre Test	Mean Post Test
Control	3.23	3.27
Experiment	3.14	3.34

Since there's an increasing mean score in the post-test both in control and experiment classes, the N-Gain score test can be carried out by using the formula (Rahardjo, 2019). The comparison graph of N-Gain between the control and experiment classes can be seen in Figure 1.

$$\text{N-Gain} = \frac{PostTest\ Score - PreTest\ Score}{Maximal\ score - PreTest} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

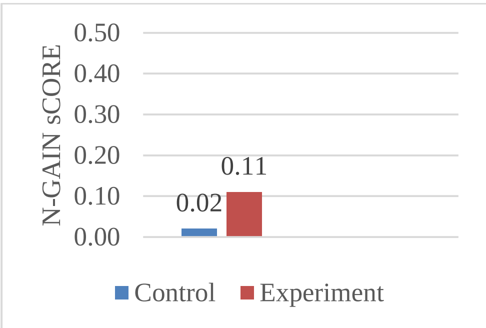

Figure 1. Graph of N-Gain between control and experiment class

The N-Gain score of the control class in all subscales is 0.02, and the N-Gain score of the experiment class is 0.11, which both categorized as low enhancement as shown in Figure 1. In answer to research question number 1, STEM PJBL does enhance students' attitudes towards STEM but not significantly. This finding is supported by Leonard et al. (2016) stated that for each group, there were no significant differences in pre-post scores on STEM attitudes. The study also stated that the treatment's duration may have affected small differences in students' STEM attitudes. Researchers suspect that the lack of significant impact on attitude towards STEM may be due to students not taking group project creation seriously enough, as Nurwahidah et al. (2021) suggest. Some students may also struggle to grasp the material despite group discussions and assistance from others, as noted by Aini et al. (2023).

However, there’s still enhancement that can be seen in the N-Gain score where the experimental class has higher mean points, indicating that students who attend the STEM-PJBL course have slightly changed their attitudes towards STEM to be more positive. The enhancement is supported by the learning stages. In the stages of implementation, students foster their STEM attitudes by designing the handmade projector, especially for the engineering and technology subscale. Engineering and technology attitudes are imperative in nurturing students' engineering design thinking, ultimately leading to the realization of their project. STEM attitudes play a pivotal role for students as they ascertain the fundamental principles of the projector, deliberate on the design, materials, and tools to be employed, and determine the appropriate dimensions of the projector. The initial product of the handmade projector developed in this stage can be seen in Figure 2.


Figure 2. Handmade Projector Before Redesign

The stage of presentation includes performing a real test of their product, calculating the focal length of the lens, and discussing the picture creation characteristics. STEM attitudes of all aspects effectively developed in this stage. Science attitudes are fostered by discussing the picture of creation which applies the concept of light. Technology and Engineering attitudes develop through the performance of product real tests, and Mathematics attitudes arise through calculating the focal length of the lens. STEM attitudes in the presentation stage needed to evaluate their own and others' products of course in science, technology, engineering, and mathematical realms. In the last stage, which is the stage of correction, the STEM attitudes are further nurtured as students rectify their self-crafted projectors based on feedback from their peers and teachers in the context of STEM disciplines. The product that has been redesigned can be seen in Figure 3.


Figure 3. Handmade Projector After Redesign

Previous studies also approve the result of the current study that STEM PJBL can be considered to enhance students' attitudes toward STEM (Yang & Chittoori, 2022; Lin et al., 2021; Kurt & Benzer, 2020; Ugras, 2018; Beier et al., 2019). The application of STEM learning in middle school has proven to have positive results in STEM attitudes (Damar et al., 2017; Özcan & Koca, 2019). The fusion of PjBL and STEM significantly impacted students' attitudes toward their future career aspirations because Students could apply the knowledge of STEM practically and generate meaningful learning via the PjBL activity (Tseng et al., 2013). STEM projects included hands-on activities such as designing and constructing products, allowing students to practice their engineering design skills in integrated content, thus positively impacting students' attitudes towards STEM (Baran et al., 2019; Sari, 2018).

Students Perception Towards Math, Science, and Engineering

Elaboration for each subscale (mathematics, science, and engineering) also showed the same results, namely, there was no significant difference between the experimental and control classes for the pre-test and post-test. Non-parametric t-test results for each subscale can be seen in Table 7.

Table 7. Nonparametric T-Test Result for Each Subscale

Subscale	Grouping Variable	Condition	Asymp. Sig. (2-tailed)
Math	Experiment and Control Class	Pre Test	.098
		Post Test	.300
Science	Experiment and Control Class	Pre Test	.680
		Post Test	.287
Engineering and Technology	Experiment and Control Class	Pre Test	.425
		Post Test	.317

-Gain scores of subscales of STEM attitudes, which are math, science, and engineering, are also determined. The N-Gain scores of all subscales are categorized as low enhancement. As can be seen in Figure 4, engineering recorded the highest mean score among all subscales. Several previous findings also stated the same result, such as Kartal & Taşdemir (2021) and Tseng et al. (2013).

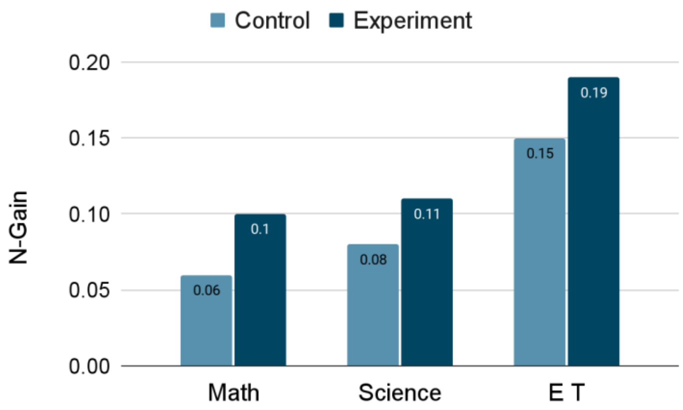

Figure. 4. N-Gain of STEM subscales

As reported in open-ended questions, most students are interested in learning to engineer because it provides something new that students have to be familiar with, as written by E14, "Engineering grows as rapidly as technology nowadays, so then I think to get used to new advance tools we have to know more about engineering", another opinion said that engineering can trigger their creativity as stated by C22 and E19, "Engineering can trigger us to use our curiosity, creative, critical thinking in making something new", another most opinion also said that engineering can produce something that can be useful for the future, E12 stated that "through engineering, we can help many people to lighten their jobs", C30 also support this opinion by stated, "by learning to engineer I hope I can make something useful for me and the society". This qualitative result is also consistent with a previous study by Hendley et al. (1996) that revealed students noticed the good impact of technology and were eager to work in related sectors because it is one of the most prominent contemporary topics. In addition, the experimental class has the highest N-Gain score in engineering, meaning students who attend the STEM PJBL course have gained their attitudes towards engineering. A study by Tseng et al. (2013) and Bingolbali (2007) has reported the same findings that STEM-PJBL is the main cause of increasing students' attitudes toward STEM in the engineering and technology subscale.

While contrary opinions were shown by students in the math subscale, most students showed negative attitudes because math is hard for them, E24 stated, "Math is hard and complicated because it has many formulas", C10 added, "It's hard to remember many formulas in math, so I need to focus more when it comes to math", another problem is most students become not interested in counting lesson, E8 writes that, "it's boring when it comes to counting lesson", C13 adds that, "*why we have to count in math class while we have a calculator?*". This result also relates to Tseng et al. (2013) finding that stated math was one the most unpopular subscales both before treatment and after treatment because students find that math is a difficult subject, Bingolbali et al. (2007) further suggested that the major reason for students' low interests in learning mathematics was because its principles are difficult and time-consuming to understand. A study by Anigbo & Indigo (2015) reveals several factors that affect the students' interest in math: teacher factor, student factor, class size, government factor, instructional strategy, math anxiety, and infrastructure.

Subscale science sets clear plus and minus aspects in students' perceptions. Some students said they enjoy science because they can have practical work in the lesson. A study by Drymiotou et al. (2021) and Blankenburg et al. (2016) stated that scientific practices or hands-on activities are one of the most frequent sources of science interest among students. Students also stated that they found science interesting because they can learn about life and living things, but when it comes to counting, mostly in physics, it is as hard as math. Williams et al. (2003) also reveal that only one-quarter of students have a positive attitude toward physics, and the rest of the students have positive attitudes toward biology. Another interesting finding is the statement of a C18 student, "Science is boring or science is exciting it depends on the teacher" Trumper (2006) supports this finding by stating in his study that the quality of teaching science can be a significant determinant of students' attitudes towards science lessons.

4. CONCLUSION

This study aims to identify the effect of STEM-PJBL learning on students' attitudes towards STEM and the findings are there is gaining in mean score in the experimental class that attended STEM-PJBL class but the gain is not significant, with only 0.11 that, categorized as a low enhancement. It may happen because the duration of the STEM-PJBL class is too short to shift students' attitudes towards STEM to be more and significantly positive. Since the gaining score is low, then there are also no significant differences between the control and experiment classes, with the t-test value shown as 0.540. The second aim is to elaborate on students' perception of math, science, and engineering and technology, this study reveals that n-gain for the engineering and technology subscale has the highest value among other subscales in both experiment and control classes because students assumed that engineering and technology can shape their critical and creative thinking by designing many devices. While students' perception of math has contrary results with engineering and technology results where most of the students have negative opinions caused by the difficulties in math, it is supported by n-gain data of math in both classes are lowest among other subscales.

This study implies that STEM-PJBL can be applied as one of the methods to enhance students' attitudes towards STEM, but teachers should find creative, innovative, and consistent ways to apply it within the science class to get a higher shifting of students' attitudes. The school also has to provide a supportive atmosphere to support STEM learning by considering STEM learning to be one of the parts of the curriculum.

Based on the result of the current study, further research may elaborate on how the period of applications of STEM-PJBL affects students' attitudes toward STEM. From the result of current research, students' attitudes towards STEM are not significantly enhanced, so it's worthwhile to explore the effect of the period of application. Also, further research about how STEM learning can shift students' perceptions to be positive for all subscales is worthy of being conducted since the current study shows that students have most negative perceptions towards math subscales, therefore developing the curriculum of STEM learning that can change students' negative perception is one of the challenges.

REFERENCES

Afriana, J., Permanasari, A., & Fitriani, A. (2016). Project-based learning integrated to enhance elementary school's student's scientific literacy. *Jurnal Pendidikan IPA Indonesia, 5(2),* 261-267.

Anigbo, L. C., & Idigo, E. (2015). FACTORS AFFECTING STUDENT'S INTEREST IN MATHEMATICS IN SECONDARY SCHOOLS IN ENUGU STATE. *Journal of Science & Computer Education, 3(3).*

Aripin, W. A., Sahidu, H., & Makhrus, M. (2021). Efektivitas perangkat pembelajaran fisika berbasis model problem based learning untuk meningkatkan kemampuan pemecahan masalah dan kemampuan berpikir kritis peserta didik. *Jurnal Penelitian dan Pembelajaran Fisika Indonesia, 3(1).*

Azhar, A. (2013). Pendidikan fisika dan keterkaitannya dengan laboratorium. *Jurnal Geliga Sains: Jurnal Pendidikan Fisika, 2(1)*, 7-12.

Baran, E., Canbazoglu Bilici, S., Mesutoglu, C., & Ocak, C. (2019). The impact of an out-of-school STEM education program on students' attitudes toward STEM and STEM careers. *School Science and Mathematics, 119,* 223–235.

Baran, M., Baran, M., Karakoyun, F., & Maskan, A. (2021). The influence of project-based STEM (PjbL-STEM) applications on the development of 21st-century skills. *Journal of Turkish Science Education, 18(4),* 798-815.b

Beier, M. E., Kim, M. H., Saterbak, A., Leautaud, V., Bishnoi, S., & Gilberto, J. M. (2019). The effect of authentic project-based learning on attitudes and career aspirations in STEM. *Journal of Research in Science Teaching, 56(1),* 3-23.

Bingolbali, E., Monaghan, J., & Roper, T. (2007). Engineering students' conceptions of the derivative and some implications for their mathematical education. *International Journal of Mathematical Education in Science and Technology, 38(6)*, 763–777.

Blankenburg, J. S., Höffler, T. N., & Parchmann, I. (2016). Fostering today what is needed tomorrow: Investigating students' interest in science. *Science education, 100(2)*, 364-391.

Bulu, V. R., & Tanggur, F. (2021). The effectiveness of STEM-based PjBL on students' critical thinking skills and collaborative attitude. *Al-Jabar: Jurnal Pendidikan Matematika, 12(1)*, 219-228.

Carnevale, A. P., Smith, N., & Melton, M. (2011). STEM: Science Technology Engineering Mathematics. *Georgetown University Center on Education and the Workforce.*

Çevik, M., & Özgünay, E. (2018). STEM Education through the Perspectives of Secondary Schools Teachers and School Administrators in Turkey. *Asian Journal of Education and Training, 4(2)*, 91-101.

Ching, Y. H., Yang, D., Wang, S., Baek, Y., Swanson, S., & Chittoori, B. (2019). Elementary school student development of STEM attitudes and perceived learning in a STEM integrated robotics curriculum. *TechTrends, 63*, 590-601.

Cook, T. D. (2015). Quasi-experimental design. *Wiley encyclopedia of management, 1-2*.

Corlu, M. S., Capraro, R. M., & Capraro, M. M. (2014). Introducing STEM education: Implications for educating our teachers in the age of innovation. *Eğitim ve Bilim, 39(171),* 74-85.

Creswell, J. W. (2014). A concise introduction to mixed methods research. SAGE publications.

Damar, A., Durmaz, C., & Önder, İ. (2017). Middle School Students' Attitudes towards STEM Applications and Their Opinions about These Applications. *Journal of Multidisciplinary Studies in Education, 1(1),* 47-65.

Dewi, P. Y., & Primayana, K. H. (2019). Effect of learning module with setting contextual teaching and learning to increase the understanding of concepts. *International Journal of Education and Learning, 1(1),* 19-26.

Drymiotou, I., Constantinou, C. P., & Avraamidou, L. (2021). Enhancing students' interest in science and understandings of STEM careers: the role of career-based scenarios. *International Journal of Science Education, 43(5),* 717-736.

Escobar, M., & Qazi, M. (2020). Builders: A project-based learning experience to foster STEM interest in students from underserved high schools. *Journal of STEM Education: Innovations and Research, 21(3).*

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American journal of theoretical and applied statistics, 5*(1), 1-4.

Galili, I., & Hazan, A. (2000). Learners' knowledge in optics: interpretation, structure and analysis. *International Journal of Science Education, 22(1),* 57-88.

Gerald, B. (2018). A brief review of independent, dependent, and one-sample t-tests. *International journal of applied mathematics and theoretical physics, 4(2),* 50-54.

Hasni, A., Bousadra, F., Belletête, V., Benabdallah, A., Nicole, M. C., & Dumais, N. (2016). Trends in research on project-based science and technology teaching and learning at K–12 levels: a systematic review. *Studies in Science Education, 52(2),* 199-231.

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

Hendley, D., Parkinson, J., Stables, A., & Tanner, H. (1995). Gender differences in pupil attitudes to the national curriculum foundation subjects of English, mathematics, science, and technology in key stage 3 in South Wales. *Educational Studies, 21,* 85–97.

Karaahmetoğlu, K., & Korkmaz, Ö. (2019). The effect of project-based Arduino educational robot applications on students' computational thinking skills and their perception of basic stem skill levels. *Participatory Educational Research, 6(2),* 1-14.

Kartal, B., & Taşdemir, A. (2021). Pre-service teachers' attitudes towards STEM: Differences based on multiple variables and the relationship with academic achievement.

Kurt, M., & Benzer, S. (2020). An Investigation on the Effect of STEM Practices on Sixth Grade Students' Academic Achievement, Problem Solving Skills, and Attitudes towards STEM. *Journal of Science Learning, 3(2),* 79-88.

Leonard, J., Buss, A., Gamboa, R., Mitchell, M., Fashola, O. S., Hubert, T., & Almughyirah, S. (2016). Using robotics and game design to enhance children's self-efficacy, STEM attitudes, and computational thinking skills. *Journal of Science Education and Technology*, *25*, 860-876.

Lin, K. Y., Lu, S. C., Hsiao, H. H., Kao, C. P., & Williams, P. J. (2021). Developing student imagination and career interest through a STEM project using 3D printing with repetitive modeling. *Interactive Learning Environments*, 1-15.

Ling, T. W. (2017). Fostering understanding and reducing misconceptions about image formation by a plane mirror using constructivist-based hands-on activities. Overcoming Students' Misconceptions in Science: Strategies and Perspectives from Malaysia, 203-222.

Lou, S. J., Chou, Y. C., Shih, R. C., & Chung, C. C. (2017). A study of creativity in CaC2 steamship-derived STEM project-based learning. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(6), 2387-2404.

Mann, H. B., & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *Annals of Mathematical Statistics*, *18*, 50– 60.

McKnight, P. E., & Najab, J. (2010). Mann-Whitney U Test. *The Corsini encyclopedia of psychology*, *1*-1.

Meltzer, D. E. (2002). The relationship between mathematics preparation and conceptual learning gains in physics: A possible "hidden variable" in diagnostic pretest scores. *American journal of physics*, *70*(12), 1259-1268.

Munifah, M., Romadhona, A. N., Ridhona, I., Ramadhani, R., Umam, R., & Tortop, H. S. (2019). How to Manage Numerical Abilities in Algebra Material? *Al-Jabar: Jurnal Pendidikan Matematika, 10(2),* 223-232.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections (Vol. 13)*. London: The Nuffield Foundation.

Özcan, H. & Koca, E. (2019). The Impact of Teaching the Subject "Pressure" with STEM Approach on the Academic Achievements of the Secondary School 7th Grade Students and Their Attitudes Towards STEM. *Education and Science, 44*(198), 201-227.

Permanasari, A., Rubini, B., & Nugroho, O. F. (2021). STEM education in Indonesia: Science teachers' and students' perspectives. *Journal of Innovation in Educational and Cultural Research, 2(1),* 7-16.

Raharjo, S. (2019). Cara Menghitung N-Gain Score Kelas Eksperimen dan Kontrol dengan SPSS. SPSS Indonesia. https://www.spssindonesia.com/2019/04/cara-menghitung-n-gain-score-spss.html

Raharjo, S. (2017). *Contoh Kasus Uji Beda Mann Whitney Menggunakan SPSS*. SPSS Indonesia. https://www.spssindonesia.com/2017/04/uji-mann-whitney-spss.html

Raharjo, S. (2015). Cara Uji Normalitas Shapiro-Wilk dengan SPSS Lengkap. SPSS Indonesia. https://www.spssindonesia.com/2015/05/cara-uji-normalitas-shapiro-wilk-dengan.html

Razali, N.M & Wah, Y.B. (2011).Power Comparisons Saphiro Wilk, Kolmogorov – Smirnov, Lilliefors and Anderson Darling Test. *Journal of Statistical Modeling and Analytics Vol.2.No.1, 21-33*, 2011

Samsudin, M. A., Jamali, S. M., Md Zain, A. N., & Ale Ebrahim, N. (2020). The effect of STEM project-based learning on self-efficacy among high-school physics students. *Journal of Turkish Science Education, 16(1),* 94-108.

Sari, U., Alıci, M., & Şen, Ö. F. (2018). The effect of STEM Instruction on attitude, career perception, and career interest in a problem-based learning environment and student opinions. *Electronic Journal of Science Education, 22,* 1–21.

Siew, N. M., & Ambo, N. (2018). Development and Evaluation of an Integrated Project-Based STEM Teaching and Learning Module on Enhancing Scientific Creativity among Fifth Graders. *Journal of Baltic Science Education*, *17*(6), 1017-1033.

Sumarni, W., & Kadarwati, S. (2020). Ethno-stem project-based learning: Its impact on critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia, 9(1),* 11-21.

Syahfira, R., Permana, N. D., Susilawati, S., & Azhar, A. (2021). Penerapan model pembelajaran inkuiri terbimbing untuk meningkatkan penguasaan konsep IPA siswa pada materi cahaya dan optik. *Indonesian Journal of education and learning, 5(1),* 16-23.

Trumper, R. (2006). Factors affecting junior high school students' interest in physics. *Journal of Science Education and Technology*, *15*, 47-58.

Tseng, K. H., Chang, C. C., Lou, S. J., & Chen, W. P. (2013). Attitudes towards science, technology, engineering, and mathematics (STEM) in a project-based learning (PjBL) environment. *International Journal of Technology and Design Education*, *23*, 87-102.

Ugras, M. (2018). The Effects of STEM Activities on STEM Attitudes, Scientific Creativity and Motivation Beliefs of the Students and Their Views on STEM Education. *International Online Journal of Educational Sciences*, *10*(5).

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM). *Journal of Psychoeducational Assessment*, *33*(7), 622-639.

Wilcoxon, F. (1945). Individual comparisons by ranking methods. *Biometrics Bulletin*, *1*, 80– 83.

Winarni, E. W., Karpudewan, M., Karyadi, B., & Gumono, G. (2022). Integrated PjBL-STEM in Scientific Literacy and Environment Attitude for Elementary School. *Asian Journal of Education and Training*, *8*(2), 43-50.

Yang, D., & Chittoori, B. (2022). Investigating Title I school student STEM attitudes and experience in an after-school problem-based bridge building project. *Journal of STEM education*, *23*(1).

Zhou, S. N., Zeng, H., Xu, S. R., Chen, L. C., & Xiao, H. (2019). Exploring Changes in Primary Students' Attitudes towards Science, Technology, Engineering and Mathematics (STEM) across Genders and Grade Levels. *Journal of Baltic Science Education, 18(3),* 466-480