Volume 13. Number 2. 191-204 DECEMBER 2024

Jurnal ilmiah pendidikan fisika Al-Biruni
https://ejournal.radenintan.ac.id/index.php/al-biruni/index
DOI: 10.24042/jipfalbiruni.v13i2.18750

P-ISSN: 2303-1832
e-ISSN: 2503-023X

The Implementation of Learning Physics with the STEM-PBL Approach to Newton's Law Materials and its Application for Character Development

Dwi Yulianti[1], Fafi Masiroh[2*]

[1,2]Department of Physics, Universitas Negeri Semarang, Indonesia

Corresponding Address: fafi.masiroh03@gmail.com

Article Info

Article history:

Received: January 11, 2024
Accepted: November 21, 2024
Published: December 30, 2024

Keywords:

character development;
physics learning;
STEM.

ABSTRACT

Globalization in the 21st Century era has the opportunity to cause a decline in character. The government tries to strengthen student character through the Pancasila Student Profile. STEM (Science, Technology, Engineering, and Mathematics) based learning can facilitate student's character. This study aims to describe the implementation of physics learning with STEM and its effect on student learning outcomes and character development. The research design employed was quasi-experimental, and the research sampling technique used was purposive sampling to determine two classes of tenth-grade students of MA Al Anwar Sarang. The experimental class integrated the STEM approach into each learning activity, and the control class used the scientific approach. Student character development was measured using observation sheets, and student learning outcomes were assessed by analyzing pretest and post-test scores. The findings of this study highlight the potential of integrating the STEM approach with Problem-Based Learning (PBL) to effectively teach Newton's Laws and develop student character. The medium-level improvement in learning outcomes (gain n = 0.399) and the high percentage of Pancasila student profile character development (81.33%) indicate that STEM-based physics learning supports academic and character-building objectives. These results suggest that optimizing all aspects of STEM integration, from learning tools to activities, is essential for fostering student character development in alignment with the Pancasila student profile. Additionally, implementing STEM-based physics learning sustainably over an extended period is recommended to enhance long-term learning outcomes and character formation.

INTRODUCTION

The development of globalization in the 21st-century civilization era affects almost every aspect of life, offering great opportunities to enhance competence, knowledge, and experience (Knapp & Krall, 2021). However, this progress is not without challenges, particularly concerning the decline in character values (Fransyaigu et al., 2021). One significant factor is the increasingly widespread and unregulated use of social media, which exposes students to a vast flow of information that is both free and easily accessible. This accessibility includes both positive and negative information, making students more susceptible to influences that may shape their attitudes, actions, and mindsets (Lonto, 2015). For instance, while social media provides platforms for learning and collaboration, it also serves as a medium for cyberbullying, misinformation, and

How to cite Yulianti, D., & Masiroh, F. (2024 The implementation of learning physics with the STEM-PBL approach to newton's law materials and its application for character development. *Jurnal ilmiah pendidikan fisika Al-Biruni, 13*(2), 191-204.

harmful content that can negatively impact students' character development. Without proper guidance, students may lack the critical thinking skills to discern positive content from negative influences.

The decline in students' character is exacerbated by teachers prioritizing curriculum targets over character education. Schools focus on academic achievements, while character education is often limited to theoretical teaching without practical application, leading students to understand concepts without truly internalizing them (Bates, 2021). Consequently, academic development dominates as the primary priority, while character education receives insufficient attention. (Komara, 2018), highlights that character formation can be achieved through continuous, long-term learning. Students' interactions with their social and cultural environments, such as Pancasila, further support this process (Omeri, 2015). Efforts to strengthen character education involve collaboration among various stakeholders to develop the Pancasila Student Profile (Maisyaroh et al., 2023; Sutrisno et al., 2023).

Character education generally focuses on five core values: religiosity, nationalism, independence, cooperation, and integrity. These values are the foundation for the dimensions of the Pancasila Student Profile, which includes elements such as noble character (Qulyubi et al., 2023), global diversity (Wiium, 2022), independence (Umami et al., 2019), cooperation (Curren, 2023), critical thinking (Umami et al., 2019), and creativity (Lassig, 2021). These core values form the basis for fostering character development in students, which is essential in everyday life and within the context of academic learning. The integration of character education into the learning process is especially significant in subjects like physics, where understanding complex concepts such as Newton's laws requires cognitive skills and the development of personal attributes like responsibility, discipline, and critical thinking. Research by (Rifyal et al., 2022) emphasizes that character development within the Pancasila Student Profile needs to be integrated into all learning materials, including physics.

Preliminary studies at MA Al-Anwar Sarang revealed that students' basic understanding of physics, particularly Newton's law and its applications, was poor. Only 20% of Class X IPA D students at MA Al-Anwar achieved the Minimum Completion Criteria score of 70 in the Mid-Semester Assessment for Newton's law material. The issue stems from a lack of character development in students' low self-awareness, responsibility, and engagement. Only 10 out of 40 students showed self-awareness by paying attention in class, impacting their understanding of the material.

One solution to address these challenges is the implementation of physics learning using the STEM (Science, Technology, Engineering, and Mathematics) approach. Research (Hebebci & Usta, 2022) shows that STEM learning positively influences students' critical thinking, problem-solving skills, and scientific creativity. Another study found that most students had a positive view of STEM, noting improvements in their attitudes and interest in class (Sari et al., 2020). This aligns with findings by (Deniş Çeliker, 2020), who stated that STEM positively influences students' characteristics and skills.

STEM-based education not only enhances cognitive abilities but also supports character development. It fosters critical thinking and creativity, aligning with the values of independence, cooperation, and integrity in the Pancasila Student Profile. STEM emphasizes fun, inspiring, interactive, and challenging activities that engage students cognitively and emotionally, helping build their character while deepening their understanding of academic subjects (Ridha et al., 2022).

Previous studies have extensively examined the STEM approach to learning (Deniş Çeliker, 2020; Hebebci & Usta, 2022). Even in problem-based learning, STEM has been shown to enhance student engagement in learning (Bicer et al., 2015; Ningsih, 2020). Other research reveals that STEM can improve students' social skills (Liu et al., 2022; Topsakal et al., 2022). However, previous studies have often been limited to general learning contexts without deeply linking them to character education goals. This study presents an innovative integration of physics learning and the STEM framework to enhance students' understanding of Newton's Laws while promoting character development. Addressing a gap in previous research that overlooked character education in physics learning, this study explores the dual impact of the STEM approach on cognitive outcomes and character growth in the Indonesian context. It aims to evaluate how the STEM-based physics learning approach influences students' mastery of Newton's Laws and their practical applications, alongside fostering essential character traits.

METHODS

The quasi-experimental design was employed with Non-equivalent Control Group Design (Sugiyono, 2022). The research was conducted at MA Al Anwar Sarang. The population was the tenth-grade students of MA Al Anwar Sarang for the 2022/2023 academic year. The research sampling technique used was purposive sampling. The subjects of this study were 34 students from class X IPA C, the experimental class, and X IPA D, the control class. Figure 1 illustrates the research flowchart, providing a clear visual representation of the sequential steps undertaken in this study, from problem identification to data analysis and conclusion.

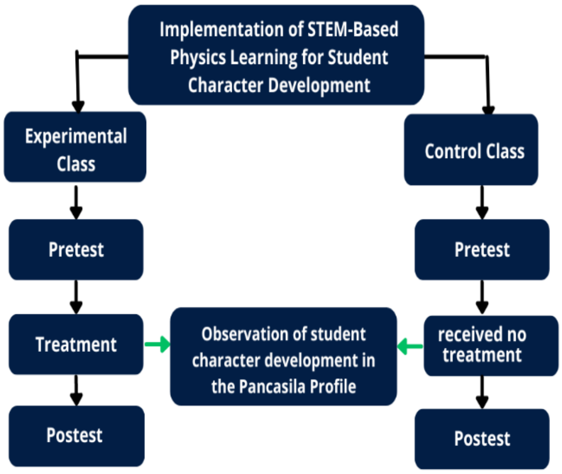

Figure 1. Research Flowchart

The variables in this research include independent variables and dependent variables. The independent variable is the implementation of physics learning with the STEM approach as a treatment for experimental class, and the dependent variable is student learning outcomes and student character development on the Pancasila student profile. This study implements Newton's law and its application in physics learning materials with the STEM approach. Data collection techniques using observation, interviews, and tests.

The instruments used in this study include test and non-test instruments. The test instruments are questions, pretests, and post-tests. The validity tested included validity, difficulty level, discriminating power, and item reliability. Testing was done using the software IBM SPSS 22. Non-test instruments include learning devices, including teaching materials, lesson plans, LDS (Student Discussion Sheets), and observation sheets. The validity of the non-test instrument was tested using a validity sheet based on the opinions of experts (judgment experts) with the results of the average category validity value of 88,56 (very feasible).

Improvement of student learning outcomes is known based on value analysis pretest and post-test in the form of homogeneity test, normality test, t-test, and n-gain test using software IBM SPSS 22. Student character development in the Pancasila Student Profile is known based on an analysis of the observation sheet.

RESULTS AND DISCUSSION

Implementation of Physics Learning with STEM-PBL Approach

The implementation of physics learning using the STEM approach in this study was carried out in class X IPA C as an experimental class. The learning activities last for three meetings, with the time allocation for each meeting being two hours of lessons (2×45 minutes). The STEM approach applied in this study is integrated into each learning tool, including lesson plans (RPP), teaching materials, and LDS (Student Discussion Sheets). Science in implementing STEM-approached physics learning in this study is the main aspect when discussing each material subchapter. The technological aspect is integrated into the discussion in each application of the basic concept of tools to facilitate work related to Newton's Laws. Engineering aspects are integrated into a discussion regarding the design process or the workings of several tools related to Newton's Laws. Mathematical aspects are then integrated into every discussion of material related to the notation of calculating magnitude.

STEM-approached physics learning activities at the first meeting began with a thirty-minute pretest to determine students' initial understanding of Newton's Law material and its application. Students are then directed to participate in further learning activities using a learning model Called problem-based learning (PBL). STEM learning in this study is implemented by inviting students to recognize concepts or knowledge from a case. Implementing STEM-PBL learning is important so that students have 21st-century skills, one of which is problem-solving skills (Bicer et al., 2015; K et al., 2023; Li et al., 2023).

Students are encouraged to conduct experiments to develop technological skills and prove scientific concepts or physical laws through mathematical data analysis (Ningsih, 2020). In STEM-based physics learning, students explore everyday phenomena related to Newton's Laws. They work in groups of 6–7 to discuss problems in the Student Discussion Sheets (LDS), understand basic concepts, and identify Newton's Laws. Students perform experiments, such as pulling a glass on paper quickly and slowly, to observe outcomes (Engineering). Throughout the three meetings, students' character development as Pancasila students are assessed based on specific indicators. Mathematical skills are integrated by formulating Newton's Law equations for various scenarios. Each group presents their findings, followed by class discussions to reinforce understanding. The 45-minute session concludes with students summarizing key concepts collaboratively.

Learning activities in the second meeting began with a review of the previous material. They continued with students discussing with the group how to draw and explain graphs of the forces acting on an inclined plane. Students are then given material reinforcement based on the results of the discussion to conclude. The learning activities at the third meeting of students carried out simple experiments by applying STEM aspects (Science, Technology, Engineering, and Mathematics) on a pulley system to analyze the relationship of force, mass, and acceleration in Newton's Laws. After being given STEM integration treatment in physics learning, The activity ends with a post-test to determine students' understanding of Newton's law material and its application.

During the STEM-approached physics learning activities, students showed quite active participation. This is because, in general, learning activities with a STEM approach invite students to connect material in everyday life to make it easier to understand (Chaiwongsa et al., 2019; Prasertsang et al., 2022). (Rahman et al.,

2022) stated that the STEM approach offers interactive and interesting learning, so students will play an active role in exploring and understanding the material in their daily lives. STEM approach learning activities related to daily activities can provide more meaning to students because students are given full opportunities to more easily understand problems, find relationships, design solutions, and solve problems (Sudarsono et al., 2022). Therefore, a positive relationship is related to student perceptions of their skills and attitudes toward applying learning with the STEM approach (Liu et al., 2022; Topsakal et al., 2022).

Student Learning Outcomes

Student learning outcomes are used to determine differences between students in the experimental and control classes in understanding Newton's Law learning material and its application. Based on the value analysis pretest and post-test in the experimental and control classes, there are concrete differences. This shows that physics learning with the STEM approach has a concrete influence on student learning outcomes (Andriani et al., 2021; Rasmi et al., 2021). These differences can be known based on the value of the pretest and post-test in the experimental and control classes in Figure 2.

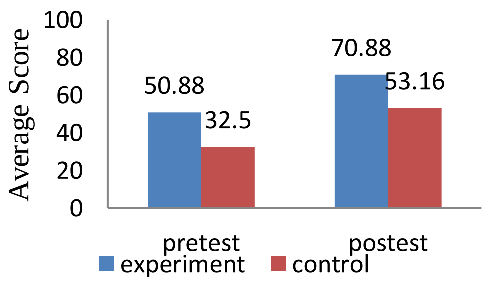

Figure 2. Average Student Learning Outcomes

The test results of the Independent Samples t-test from the score of the post-test experimental class and control class are declared homogeneous and normally distributed. This proves that there are differences between the experimental and control classes in learning outcomes. Table 1 shows the results of the test Independent Samples t-test.

Table 1. Test Results Independent Samples t-test

F	sig.	T	df	sig.(*2-tailed*)
2,712	0,146	-7373	62	0,000

The analysis in Table 2 shows the sig. (2-tailed) obtained 0,000 $<$ 0,05 and$t_{count} < t_{table}$is -7,373$<$ -1,998 p at 5% significance, so it can be concluded that there is a difference in the implementation of physics learning with the STEM approach to student learning outcomes compared to the application of ordinary physics learning.

The current experimental class learning outcomes, such as the pretest before treatment and the post-test after treatment, also experienced a difference. This is evidenced in the test acquisition Paired Sample t-test from score pretest and post-test experimental class after the data was declared homogeneous and normally distributed. Results of the test Paired Sample t-test are shown in Table 2.

Table 2. Test Results Paired Samples Test

t	Df	sig. (*2-tailed*)
-11,334	33	0,000

Paired Sample t-test in Table 3 shows that the value significance (2-tailed) is 0,000 $<$ 0,05 and $-t_{count}$ is -11,334 with a value $-t_{table}$ is -2,034 at significance 5%. Therefore, $t_{count} < t_{table}$ so means there are differences in student learning outcomes in the experimental class before and after the implementation of physics learning with the STEM approach. The average student learning outcomes in the experimental class after implementing the STEM approach to physics learning have increased. The increase in student learning outcomes in the experimental class is supported by the results of both classes' analysis pretest and post-test on the test N-gain. Test N gain is presented in Table 3.

Table 3. Test Score N-gain Student Learning Outcomes

Class	Average value		<g>	Criteria
	Pretest	Postest		
Experiment	50,88	70,88	0,399	Medium
Control	32,5	53,16	0,284	Low

Based on Table 3, a score of 0.399 was obtained for N-gain student learning outcomes in the experimental class. The large score indicates that student learning outcomes in the experimental class are included in the moderate criteria. The moderate criterion obtained in the experimental class is due to a treatment that implemented physics learning with a STEM approach.

Improved student learning outcomes in the experimental class because the implementation of the STEM approach invites students to think critically by collaborating and innovating with each other so that they not only memorize but understand material concepts (Okta et al., 2018). STEM-approached physics learning activities indirectly attract students' interest. This statement is relevant in (Ozkan & Kettler, 2022) research when directing students to carry out learning activities with a STEM approach that they experienced an increase in integrating mathematical operations into the product manufacturing stage efficiently because STEM has a flexible structure in the integration process and adapts learning to students' needs in everyday life. The results (Neher-Asylbekov & Wagner, 2023) show that the active participation of students through learning with the STEM approach increases student interest in the learning environment so that students can understand more about learning material. Increased student motivation through the implementation of learning with a STEM approach is also mentioned in (Büyükdede & Tanel 2019) research so that students can understand more about the fields of Science, Technology, Engineering, and Mathematics. This is what encourages students' cognitive influence in a positive way (De Loof et al., 2022). Therefore, the learning outcomes of experimental class students have increased through the implementation of STEM learning approaches.

Student Character Development

Physics learning with the STEM approach is integrated with character development in each learning tool, which includes lesson plans (RPP), teaching materials, and LDS (Student Discussion Sheets). The profile of Pancasila students includes six characteristics: faith, piety to God Almighty and noble character, global diversity, independence, working together, critical reasoning, and creativity. Student character development is observed with the help of observation sheets, which include six Pancasila.

a. Have Faith, Fear of God Almighty, and Have Noble Characters

The development of the character of faith, piety to God Almighty, and noble character is observed based on several indicators, which include religious morals, personal morals, morals towards humans, morals towards nature, and national morals (Hajaroh et al., 2023; Muhtar et al., 2019). These indicators are more specific, covering several aspects, including 1) starting learning with greetings and praying, 2) discussing without disputing, and 3) obeying the teacher's recommendations politely. The results of observing the character development of faith, piety to God Almighty, and having noble character with the help of observation sheets are presented in Figure 3.

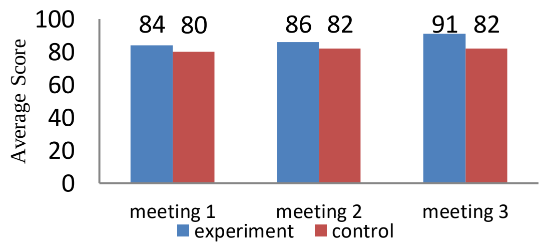

Figure 3. Graph of Character Development of Faith,Fear of God YME, and Noble Morals

Figure 3 shows the difference in the average score for developing faith, piety to God Almighty, and noble character between the experimental class and the control class. The experimental class's implementation of the STEM approach to physics learning, which integrates character development, has a higher average score than the control class in each meeting.

The average score for developing the character of faith, piety to God Almighty, and having a noble character in the experimental class is 87%, which is classified as a cultural criterion. This can be seen when students in the experimental class can discuss and make connections between their understanding of the material and religious knowledge. One interprets the concept of Newton's Second Law, and they understand that the amount of pleasure they get is proportional to the effort in worshiping God Almighty. This is in line with the sound of Newton's Second Law, which states that "*Acceleration (a) produced by the resultant force (∑F) acting on an object is proportional to and in the direction of the resultant force*." The ability of the experimental class students is because, through the STEM approach, they can understand material concepts more easily. Hence, they can relate them to the meaning of everyday life.

The application of character development in learning activities significantly fosters noble character and an outstanding personality in each student (Adha, 2011; Carr, 2023; Miller, 2023). This is further supported by findings that STEM-based learning can effectively address gaps in developing students' religious character (Sumarni et al., 2020).

b. Global Diversity

Figure 4 presents the results of observing the development of global diversity characters using observation sheets.

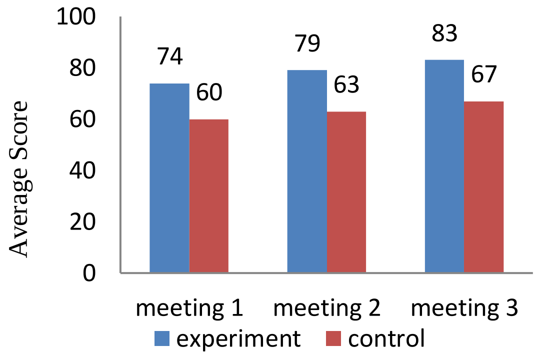

Figure 4. Graph of Global Diversity Development

The character of global diversity has several indicators, which include intercultural communication skills, knowing and appreciating culture, reflection, and responsibility for the experience of diversity. These indicators assess the character of global diversity, more specifically in respecting peers' opinions, concluding opinions politely, and drawing conclusions from various opinions.

Based on Figure 3, the global diversity of characters in the experimental class experienced a significant development at each meeting, so it had a greater average than the control class. Communicative skills are one of the aspects observed in the development of global diversity characters. It was shown in this study that during learning activities, experimental class students began to show global diversity characteristics, for example, by respecting friends' opinions to conclude various opinions. Students' abilities to communicate experience development during learning activities with a STEM approach (Yulianti et al., 2020). This invites students to get to know and appreciate each other by the indicators of the character of global diversity.

c. Independent

The results of observations of independent character development are presented in Figure 5.

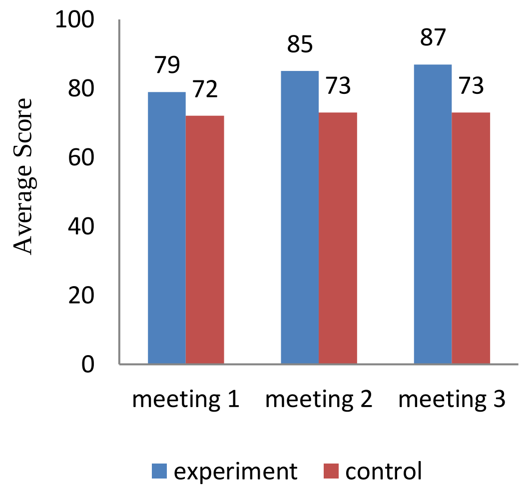

Figure 5. Graph of Independent Character Development

Independent character development has indicators of self-awareness, the situation at hand, and self-regulation. These indicators specifically cover aspects of 1) having awareness to carry out assignments from the teacher without depending on other friends, 2) being on time when attending lessons, and 3) finding out learning material through various sources.

Based on Figure 4. it can be seen that the independent character of the experimental class has developed. Most of the students in the experimental class began to show independent character by using the STEM approach in learning. For example, students do assignments from various sources to organize thoughts, feelings, and behavior to achieve their learning goals. The existence of STEM implementation, which invites students to explore in a guided manner, influences student independence, which is one of the characteristics of Pancasila students. The STEM learning approach can build Students' independent character (Budiarti et al., 2023; Sofyan et al., 2021). It can be observed that during learning activities, students actively explore knowledge without relying on other people, so they are brave enough to express their opinions.

d. Mutual Cooperation

The results of observations of cooperation character development are presented in Figure 6.

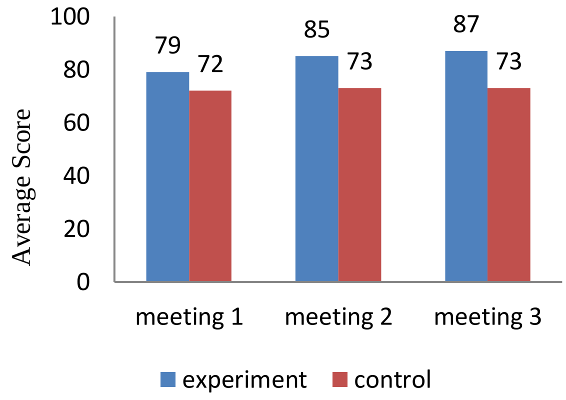

Figure 6. Graph of Mutual Cooperation Character Development

The indicators of cooperation character development consist of collaboration, caring, and sharing. More specific aspects to observe from these indicators include 1) Working with friends during group discussions, 2) Helping friends when they experience learning difficulties, and 3) Sharing knowledge between friends by assisting according to each other's capabilities.

Based on Figure 4.5, the character of cooperation in the experimental class has developed optimally. The results of the average score of cooperation character observations increased at each experimental class meeting and, as a whole, were included in the cultured category with a percentage of 84%. Students in the experimental class are directed to work together in teams through the implementation of learning with the STEM approach (Erlinawati et al., 2019).

This was proven during learning activities. Students discussed with each other in groups to assist in finding solutions to the problems discussed according to their capabilities. Such attitudes show concern and awareness of students' influence and experience development with the STEM learning approach. This is in line with previous research that learning with a STEM approach generally includes group activities such as practicums, discussions, and presentations so that it requires students to work together and work together with each other (Chaiwongsa et al., 2019; Wieselmann et al., 2021). Learning content with a STEM approach is delivered using teaching materials with a STEM approach. These teaching materials facilitate students' collaboration as a manifestation of cooperation. This follows Indonesian students' cooperation abilities, including being able to carry out activities together and unsourced so that they are carried out easily (Irawati et al., 2022).

Teaching materials with a STEM approach in the experimental class introduces students more to phenomena around as an application of Newton's law material and its application to be discussed together. Teaching materials in the control class tend to discuss the material monotonously, so students prefer to focus on themselves to understand the learning material. Therefore, indirectly learning with the STEM approach influences students to collaborate and interact positively in teams toward problem-solving (Yulianti et al., 2020).

e. Critical Reasoning

The indicators of critical reasoning character in the Pancasila student profile include earning and processing information and ideas, analyzing and evaluating, reflecting on thoughts, and making decisions. Aspects observed during learning activities from these indicators include 1) expressing opinions by identifying and processing the information obtained, 2) describing solutions and making decisions on a problem, and 3) answering questions critically, relevantly, and precisely.

This study implements physics learning with the STEM approach and invites students to analyze and evaluate problems, including their solutions. This activity will train students' critical reasoning power to make decisions and determine conclusions. The results of observations of students' critical reasoning character development are presented in Figure 7.

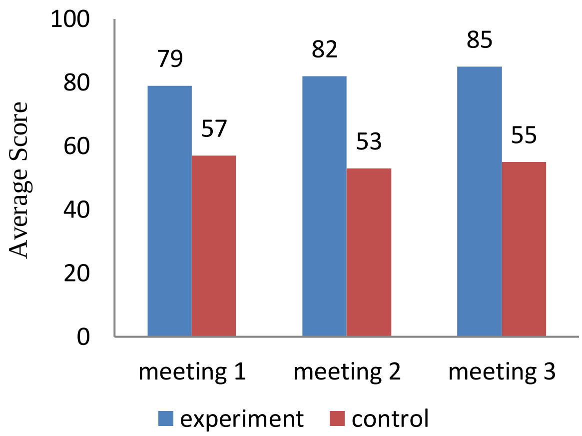

Figure 7. Graph of Critical Reasoning Character Development

Based on Figure 6, it can be seen that the students' critical reasoning abilities in the experimental class have developed, so the average score each week reaches 82% in the cultured category. (Macalalag et al., 2022) His research also stated that the implementation of learning with the STEM approach has the potential to support students' skills in critical thinking and problem-solving. In line with previous research, the implementation of learning with a STEM approach optimizes students' abilities to analyze problems related to everyday life (Yulianti et al., 2020). This encourages students' interest in class so that they pay full attention to understanding the concept of learning material.

f. Creative

Indicators of creative character development in the Pancasila student profile include producing original ideas, works, and actions. Assessment through these indicators has more specific aspects to be observed during learning activities, including 1) generating ideas from the simplest things that are original, 2) applying these ideas according to context as solutions to various alternative problems, and 3) producing original works from ideas that obtained concerning the material. The results of observations of students' creative character development in the Pancasila student profile are presented in Figure 8.

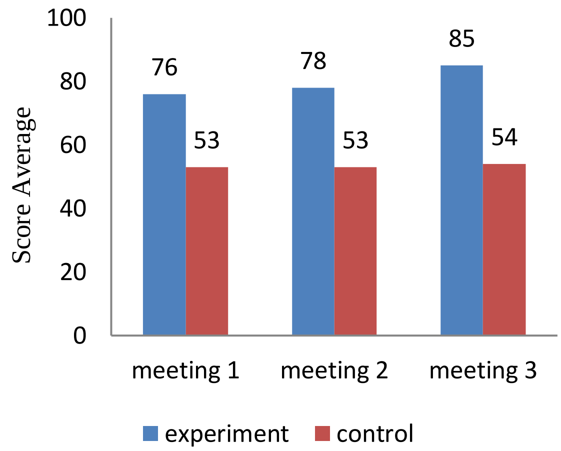

Figure 8. Graph of Creative Character Development

Figure 7 shows that experimental class students have sufficiently maximal creative character development with an average of 79% in all meetings included in the starting to develop category. In line with previous research, learning the STEM approach in its implementation offers full opportunities for students to find creative solutions to a problem discussed (Erlinawati et al., 2019).

STEM learning significantly influences students' creative character, for example, in terms of imagination, curiosity, and completing challenges to find a solution to a problem (Hebebci & Usta, 2022). Students' creativity during learning with the STEM approach has developed because it invites them to find original ideas for solving the problems that have been presented (Yulianti et al., 2022). This follows the purpose of implementing STEM to provide students with experience through the ideas found in solving problems.

CONCLUSION AND SUGGESTION

Based on the research results, it can be concluded that the implementation of physics learning with the STEM approach in this study focuses on Newton's law material and its application using learning models such as problem-based learning. In its implementation in this study, STEM is integrated with each learning tool to facilitate student character development. Student learning outcomes in the experimental class through physics learning with the STEM approach increased with a gain n value of 0.399 in the medium category as measured by value pretest and post-test. After the implementation of physics learning with the STEM approach, students in the experimental class experienced the development of the Pancasila student profile character with an overall average percentage of 81.33% in the cultured category.

This study advises that physics learning with a STEM approach needs to maximize every aspect of STEM to facilitate the development of student character in the Pancasila student profile, namely in every learning device and learning activity. Physics learning with the STEM approach is expected to be implemented over a longer period and sustainably to facilitate learning outcomes and student character development in the Pancasila student profile.

AUTHOR CONTRIBUTIONS

DY: Collection of Data, Critical Revision of The Article, Finalization of Article; FM: Research Concept and Design, Collection of Data, Data Analysis and Interpretation, Writing The Article.

REFERENCES

Adha, M. M. (2011). Pemahaman dan Implementasi Nilai Karakter dalam Kehidupan Sehari-Hari. *Media Komunikasi FPIPS*, *10*(2), 219–228.

Andriani, P., Ali, M., & Jarnawi, M. (2021). The influence of science, technology, engineering, and mathematics (STEM) learning approaches on learning outcomes. *Journal of Physics: Conference Series*, *2126*(1), 012017. https://doi.org/10.1088/1742-6596/2126/1/012017

Bates, A. (2021). *Moral Emotions and Human Interdependence in Character Education: Beyond the One-Dimensional Self* (1st ed.). Routledge. https://doi.org/10.4324/9781003049500

Bicer, A., Boedeker, P., Capraro, R. M., & Capraro, M. M. (2015). The Effects of STEM PBL on Students' Mathematical and Scientific Vocabulary Knowledge. *International Journal of Contemporary Educational Research*, *2*(2), 69–75.

Budiarti, R. S., Johari, A., & Anggereini, E. (2023). Analysis of stem integrated PjBL learning designs in biology learning to grow character building. *Journal of Entomological Research*, *47*(suppl), 1046–1049. https://doi.org/10.5958/0974-4576.2023.00196.2

Büyükdede, M., & Tanel, R. (2019). Effect of the stem activities related to work-energy topics on academic achievement and prospective teachers' opinions on stem activities. *Journal of Baltic Science Education*, *18*(4), 507–518. https://doi.org/10.33225/jbse/19.18.507

Carr, D. (2023). The Hazards of Role Modelling for the Education of Moral and/or Virtuous Character. *Philosophical Inquiry in Education*, *30*(1), 68–79. https://doi.org/10.7202/1099903ar

Chaiwongsa, P., Kinboon, N., & Yanasarn, N. (2019). STEM - Play, Learn and Work: STEM Education in Academic Club Based on Community and Local Products to Improve a Positive Attitude towards STEM. *Journal of Physics: Conference Series*, *1340*(1), 012004. https://doi.org/10.1088/1742-6596/1340/1/012004

Curren, R. (2023). Superar lo que nos divide: La Amistad Cívica Global y «El pleno desarrollo de la Personalidad Humana». *Revista Española de Pedagogía*, *81*(284). https://doi.org/10.22550/REP81-1-2023-02

De Loof, H., Boeve-de Pauw, J., & Van Petegem, P. (2022). Integrated STEM Education: The Effects of a Long-Term Intervention on Students' Cognitive Performance. *European Journal of STEM Education*, *7*(1), 13. https://doi.org/10.20897/ejsteme/12738

Deniş Çeliker, H. (2020). The Effects of Scenario-Based STEM Project Design Process with Pre-service Science Teachers: 21st Century Skills and Competencies, Integrative STEM Teaching Intentions and STEM Attitudes. *Journal of Educational Issues*, *6*(2), 451. https://doi.org/10.5296/jei.v6i2.17993

Erlinawati, C. E., Bektiarso, S., & Maryani, M. (2019). Model pembelajaran project based learning berbasis stem pada pembelajaran fisika. *FKIP e-PROCEEDING*, *4*(1), 1–4.

Fransyaigu, R., Asnawi, A., Ramadhani, D., & Mulyahati, B. (2021). Implementation of Strengthening Technology-Based Character Education in Elementary Schools. *ICLIQE 2021: Proceeding of The 5th International Conference on Learning Innovation and Quality Education*, 1–6. https://doi.org/10.1145/3516875.3516960

Hajaroh, M., Dwiningrum, S. I. A., & Rukiyati, R. (2023). Development of the Theoretical Construction Model of Muslim Religious Character with Confirmatory Factor Analysis to Develop a Measurement Scale. *International Journal of Islamic Thought*, *23*(1). https://doi.org/10.24035/ijit.23.2023.257

Hebebci, M. T., & Usta, E. (2022). The Effects of Integrated STEM Education Practices on Problem Solving Skills, Scientific Creativity, and Critical Thinking Dispositions. *Participatory Educational Research*, *9*(6), 358–379. https://doi.org/10.17275/per.22.143.9.6

Irawati, D., Iqbal, A. M., Hasanah, A., & Arifin, B. S. (2022). Profil Pelajar Pancasila Sebagai Upaya Mewujudkan Karakter Bangsa. *Edumaspul: Jurnal Pendidikan*, *6*(1), 1224–1238. https://doi.org/10.33487/edumaspul.v6i1.3622

K, P. V., P, Y., & N, S. K. (2023). Researching the ESL Classroom: Promoting Critical Thinking and Speaking Skills Through Role-Plays – A Study Among Tertiary Level Learners in the STEM Context Through Action Research. *2023 Intelligent Computing and Control for Engineering and Business Systems (ICCEBS)*, 1–8. https://doi.org/10.1109/ICCEBS58601.2023.10449204

Knapp, G., & Krall, H. (Eds.). (2021). *Youth Cultures in a Globalized World: Developments, Analyses and Perspectives*. Springer International Publishing. https://doi.org/10.1007/978-3-030-65177-0

Komara, E. (2018). Penguatan Pendidikan Karakter dan Pembelajaran Abad 21. *SIPATAHOENAN: South-East Asian Journal for Youth, Sports & Health Education*, *4*(1), 17–26.

Lassig, C. (2021). Creativity Talent Development: Fostering Creativity in Schools. In S. R. Smith (Ed.), *Handbook of Giftedness and Talent Development in the Asia-Pacific* (pp. 1045–1069). Springer Singapore. https://doi.org/10.1007/978-981-13-3041-4_49

Li, J.-J., Zhang, Y., & Liu, J.-F. (2023). Investigating the Relationships among Students' Motivational Beliefs, Behavioural Engagement and Problem-solving Ability in STEM Education. *2023 7th International Conference on Digital Technology in Education*, 123–128. https://doi.org/10.1145/3626686.3631650

Liu, S.-J., Zhou, S.-N., Xu, S.-R., & Xiao, H. (2022). Exploring effect on primary school students' stem attitude determined via structural equation modeling. *Journal of Baltic Science Education*, *21*(6), 1052–1068. https://doi.org/10.33225/jbse/22.21.1052

Lonto, A. L. (2015). Pengembangan Model Pendidikan Karakter Berbasis Nilai Sosio-Kultural pada Siswa SMA di Minahasa. *MIMBAR, Jurnal Sosial Dan Pembangunan*, *31*(2), 319. https://doi.org/10.29313/mimbar.v31i2.1416

Macalalag, A. Z., Sahin, I., Johnson, J., & Bicer, A. (2022). *Internalization of STEM Education*. ISTES Organization.

Maisyaroh, M., Untari, S., Chusniyah, T., Adha, M. A., Prestiadi, D., & Ariyanti, N. S. (2023). Strengthening character education planning based on Pancasila value in the international class program. *International Journal of Evaluation and Research in Education (IJERE)*, *12*(1), 149. https://doi.org/10.11591/ijere.v12i1.24161

Miller, T. W. (2023). Character Education Update: Building a Buffer Against School Violence. In T. W. Miller (Ed.), *School Violence and Primary Prevention* (pp. 605–618). Springer International Publishing. https://doi.org/10.1007/978-3-031-13134-9_24

Muhtar, T., Supriyadi, T., Lengkana, A. S., & Hanifah, S. (2019). Religious Characters-Based Physical Education Learning in Elementary School. *International Journal of Learning, Teaching and Educational Research*, *18*(12), 211–239. https://doi.org/10.26803/ijlter.18.12.13

Neher-Asylbekov, S., & Wagner, I. (2023). Effects of Out-of-School STEM Learning Environments on Student Interest: A Critical Systematic Literature Review. *Journal for STEM Education Research*, *6*(1), 1–44. https://doi.org/10.1007/s41979-022-00080-8

Ningsih, S. I. P. (2020). Penerapan model pembelajaran PBL terintegrasi stem untuk meningkatkan aktivitas dan hasil belajar peserta didik di kelas XII IPA 5 SMAN 7 Padang. *Pillar of Physics Education*, *13*(3), 443–450.

Okta, P. D., Yennita, Y., & Ansori, I. (2018). Penerapan model pembelajaran berbasis masalah untuk meningkatkan hasil belajar IPA. *Diklabio: Jurnal Pendidikan Dan Pembelajaran Biologi*, *2*(1), 86–95. https://doi.org/10.33369/diklabio.2.1.86-95

Omeri, N. (2015). Pentingnya pendidikan karakter dalam dunia pendidikan. *Manajer Pendidikan: Jurnal Ilmiah Manajemen Pendidikan Program Pascasarjana*, *9*(3), 464–468.

Ozkan, F., & Kettler, T. (2022). Effects of STEM education on the academic success and social-emotional development of gifted students. *Journal of Gifted Education and Creativity*, *9*(2), 143–163.

Prasertsang, P., Komal, A., Nilvon, S., Worapun, W., & Lamjuanjit, Y. (2022). STEM Education-Based Learning Management for Creative Thinking Development: Length Measurement Lessons of Grade 3 Students. *Journal of Educational Issues*, *8*(2), 603. https://doi.org/10.5296/jei.v8i2.20093

Qulyubi, M., Leksono, A. A., & Khori, A. (2023). The Development of Noble Character Through The Program, Child-Friendly Schools. *Munaddhomah: Jurnal Manajemen Pendidikan Islam*, *4*(1), 144–154. https://doi.org/10.31538/munaddhomah.v4i1.343

Rahman, N. A., Rosli, R., Rambely, A. S., Siregar, N. C., Capraro, M. M., & Capraro, R. M. (2022). Secondary school teachers' perceptions of STEM pedagogical content knowledge. *Journal on Mathematics Education*, *13*(1), 119–134. https://doi.org/10.22342/jme.v13i1.pp119-134

Rasmi, D. P., Sanjaya, L. A., Hendri, M., Yoandina, A., Putri, R. A., Puspa D., R. W., Dinata, F. A., Ilmi, N., Winarko, H. B., Pertiwi, W. A., Rasimin, & Qoiriyah, W. (2021). *Implementation of STEM learning using the slingshot toy project on elasticity and Hooke's law*. 020027. https://doi.org/10.1063/5.0037599

Ridha, M. R., Zuhdi, M., & Ayub, S. (2022). Pengembangan Perangkat Pembelajaran PjBL berbasis STEM dalam Meningkatkan Kreativitas Fisika Peserta Didik. *Jurnal Ilmiah Profesi Pendidikan*, *7*(1), 223–228. https://doi.org/10.29303/jipp.v7i1.447

Rifyal, M., Sartika, D., & Kalsum, U. (2022). Integrasi pendidikan karakter dalam pembelajaran fisika: materi alat optik. *PHYDAGOGIC : Jurnal Fisika Dan Pembelajarannya*, *4*(2), 83–88. https://doi.org/10.31605/phy.v4i2.1650

Sari, U., Duygu, E., Şen, Ö. F., & Kirindi, T. (2020). The Effects of STEM Education on Scientific Process Skills and STEM Awareness in Simulation Based Inquiry Learning Environment. *Journal of Turkish Science Education*, 3. https://doi.org/10.36681/tused.2020.34

Sofyan, H., Irwandi, I., Artika, W., Oktavia, R., Lubis, Z. A., & Sari, I. M. (2021). The Integration of STEMC in Indonesia: Current Status and Future Prospects. *2021 2nd SEA-STEM International Conference (SEA-*

STEM), 177–180. https://doi.org/10.1109/SEA-STEM53614.2021.9668108

Sudarsono, S., Kartono, K., Mulyono, M., & Mariani, S. (2022). The Effect of STEM Model Based on Bima's Local Cultural on Problem Solving Ability. *International Journal of Instruction*, *15*(2), 83–96. https://doi.org/10.29333/iji.2022.1525a

Sugiyono. (2022). *Metode penelitian pendidikan: (Pendekatan kuantitatif, kualitatif dan R & D)* (Setiyawami, Ed.; 3rd ed.). alfabeta.

Sumarni, W., Faizah, Z., Subali, B., Wiyanto, W., & Ellianawati, E. (2020). The urgency of religious and cultural science in STEM education: A meta data analysis. *International Journal of Evaluation and Research in Education (IJERE)*, *9*(4), 1045. https://doi.org/10.11591/ijere.v9i4.20462

Sutrisno, S., Firdaus, L. N., Hadriana, Sumarno, & Hainul Putra, Z. (2023). Ethnoeconomic Learning Approach to Strengthen the Profile of Pancasila Students in a Globally Diverse Environment. *BIO Web of Conferences*, *79*, 06005. https://doi.org/10.1051/bioconf/20237906005

Topsakal, İ., Yalçın, S. A., & Çakır, Z. (2022). The Effect of Problem-based STEM Education on the Students' Critical Thinking Tendencies and Their Perceptions for Problem Solving Skills. *Science Education International*, *33*(2), 136–145. https://doi.org/10.33828/sei.v33.i2.1

Umami, İ., Gani, A., & WaskiTo, T. (2019). Proposal of Character and Moral Education for Gifted Young Scientists in Indonesia. *Journal for the Education of Gifted Young Scientists*, *7*(2), 377–387. https://doi.org/10.17478/jegys.579560

Wieselmann, J. R., Dare, E. A., Roehrig, G. H., & Ring-Whalen, E. A. (2021). "There are other ways to help besides using the stuff": Using activity theory to understand dynamic student participation in small group science, technology, engineering, and mathematics activities. *Journal of Research in Science Teaching*, *58*(9), 1281–1319. https://doi.org/10.1002/tea.21710

Wiium, N. (2022). Character, Diversity Values, and Civic Engagement Among Norwegian Youth. In L. Dutra-Thomé, D. F. Rabelo, D. Ramos, & E. F. Góes (Eds.), *Racism and Human Development* (pp. 133–149). Springer International Publishing. https://doi.org/10.1007/978-3-030-83545-3_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. https://doi.org/10.15294/jpii.v11i1.32607

Yulianti, D., Wiyanto, Rusilowati, A., & Nugroho, S. E. (2020). Physics Teaching Materials Based on Science Technology Engineering and Mathematics to Develop Communication and Collaboration Skills. *Proceedings of the International Conference on Science and Education and Technology (ISET 2019)*. International Conference on Science and Education and Technology (ISET 2019), Kota Semarang, Indonesia. https://doi.org/10.2991/assehr.k.200620.086