International Journal of Evaluation and Research in Education (IJERE)
Vol. 13, No. 4, August 2024, pp. 2585~2593
ISSN: 2252-8822, DOI: 10.11591/ijere.v13i4.28894

Developing STEM project-based learning module for primary school teachers: a need analysis

Riski Septiadevana[1], Norazilawati Abdullah[1,2]
[1]Faculty of Human Development, Universiti Pendidikan Sultan Idris, Tanjong Malim, Malaysia
[2]National Child Development Research Centre, Universiti Pendidikan Sultan Idris, Tanjong Malim, Malaysia

Article Info

Article history:

Received Oct 31, 2023
Revised Dec 19, 2023
Accepted Jan 29, 2024

Keywords:

Need analysis
Primary school
Project-based learning
Science learning
STEM module

ABSTRACT

The integration of science, technology, engineering, and mathematics (STEM) with project-based learning is beneficial in facilitating students to compete effectively in the 21st century, but teachers still encounter obstacles, so in implementation, especially in primary schools, is still rarely done. Therefore, it is necessary to develop STEM project-based learning module to overcome teacher problems. This study aims to collect and analyze teacher perspectives regarding their requirements for the development of STEM project-based learning module. This study was conducted using a design and developmental research (DDR) approach. The first phase included need analysis, carried out through an online questionnaire. The participants consisted of 397 teachers in Cirebon and the results showed that primary school teachers required STEM project-based learning module to facilitate the development of relevant skills in the 21st century, such as scientific literacy and critical thinking. Based on the data collected, the most difficult topic and the topic with the highest forms of misconceptions appeared to be human body organ systems, with a percentage value of 21.16% and matter and change, with a percentage at 21.41%. STEM project-based learning module for primary school level can be developed for various topics such as human body organs or matter and changes.

Corresponding Author:

Norazilawati Abdullah
Faculty of Human Development, Universiti Pendidikan Sultan Idris
Tanjong Malim, Perak, Malaysia
Email: nora@fpm.upsi.edu.my

1. INTRODUCTION

Science, technology, engineering, and mathematics (STEM) is an interdisciplinary field where these different disciplines mutually reinforce and support each other, fostering a holistic approach to problem-solving and innovation [1]. In this field, the contents of subjects are not separated but viewed as dynamic and fluid, with teachers, specifically those in STEM, emphasizing an integrated approach to teaching and learning [2]. Therefore, STEM education serves as an alternative approach to prepare students for the challenges of the 21st century. It aims to promote and support the development of critical thinking, problem-solving, creativity, and scientific literacy in students, starting from an early age [3]–[5].

Furthermore, adapting the conceptual framework of STEM education to Indonesian policy will be considered in three parts: technology, science, and mathematics. A characteristic of Indonesian science, mathematics and technology is that knowledge is always linked to Almighty God, the social life of the society and nation, and local wisdom such as natural conditions [6]. This characteristic of STEM learning in Indonesia can be implemented through project-based learning. STEM integrated with project-based learning

can make learning more student-centered and more meaningful because students are given the opportunity to make connections between learning and the real world [7]. This type of learning is a significant teaching strategy aimed at preparing and equipping students for the workforce and for thriving future lives [8]. It is crucial to acknowledge that the pedagogical concept of project-based learning differs from traditional learning. This approach promotes learning through inquiry, encourages collaborative problem-solving that reflects the thought processes of students, and piques the interest of students by connecting learning to topics related to everyday life [9], [10].

At primary school level, learning science is expected to establish a foundation and provide students with the opportunity to explore the environment and connect it to their everyday lives. This early exposure to science in primary school serves to nurture the interests of students in and aspirations for science-related fields and careers. However, it is essential to clarify that primary school students often have limited opportunities to actively engage with scientific practices in relation to science content [11]. STEM education is related to the application of scientific learning in their science classrooms [12]. STEM education is widely used by teachers as a context and real-life problems, and is believed to create interesting learning, help the achievement of affective and cognitive domains in science learning, increase student interest, and subsequently students can solve problems while learning science [13]. In developing countries like Indonesia, STEM learning remains infrequent, specifically at primary school level. This is a concern, as it can lead to a lack of a solid foundation for science-related subjects among students. As a result, when these learners progress to middle and high school, they may lose interest in STEM subjects due to the absence of solid groundwork [14].

As observed from previous studies, most teachers have recognized STEM education as the integration of technology, engineering, and mathematics into science, but only approximately half of these educators have practical experience with STEM learning [12]. However, it is essential to acknowledge that STEM education or project-based learning approach can significantly enhance the scientific literacy and critical thinking skills of students [15]. Scientific literacy, in this context, comprises the capacity to engage with science-related issues and ideas. It emphasizes the ability to apply scientific knowledge in real-life contexts as reflective citizens.

On the other hand, critical thinking is a disciplined process that includes active and skillful conceptualization, application, analysis, synthesis, and evaluation of information gathered from observation, experience, reflection, reasoning, or communication. It serves as a guide for forming beliefs and taking action [16]. In the implementation of STEM learning, teachers encounter various challenges that indirectly impede its adoption in the classroom. These challenges include limited time [1], [17], a shortage of learning resources such as modules, worksheets, and books [18], difficulty in selecting appropriate strategies and projects [19], student attitude [20], teacher skills [21], and school demographics [22]. The scarcity of STEM study in relation to various subjects, media, and learning strategies in Indonesia presents opportunities for educational examinations to explore and contribute to this field [23].

Both STEM education and project-based learning offer valuable hands-on learning experiences that empower students to apply their existing knowledge to solve real-life problems [24], [25]. However, the effective implementation of this form of learning, which comprises aspects like design, collaboration, and differentiation, can be challenging. Based on this insight, teachers often require practical examples, detailed guidance, and models of best practices to navigate this approach successfully [26]. Another equally vital aspect is the provision of materials, activities, and resources that can aid in fostering the development of relevant skills in this 21st century among students [27]. In this regard, to simplify the need for an overview of learning strategies and necessary teaching materials, modules can be instrumental and readily used by both teachers and students in school. However, in Indonesia, many of these existing modules have been found to not be in line with the characteristics of STEM-based learning materials [21].

It is also crucial to clarify that previous studies conducted with a focus on the development of STEM project-based learning modules were predominantly carried out at the secondary or university levels [28], [29]. In accordance with this, the development of such a solution for primary schools remains relatively uncommon. Considering the identified study problem, there is need for a solution that offers STEM education using project-based learning approach, presented in the form of modules. In this regard, these learning approaches should be developed with the purpose of cultivating 21st century skills, including scientific literacy and critical thinking, among primary school students. Therefore, this study aims to assess the need for the development of STEM module based on project-based learning approach for primary school teachers.

2. METHOD

2.1. Study design

This study utilizes the design and developmental research (DDR) approach, which was introduced by Richey and Klein [30]. This approach is particularly well-suited for explorations characterized by the goal of producing a final decision or creating new elements, such as models, modules, frameworks, taxonomies, and similar studies [31]. Furthermore, the DDR approach consists of three phases including need analysis phase, the design and development phase, and the assessment phase. It is essential to clarify that each phase uses distinct methods for sample selection, instrument usage and data analysis. For this particular study, the focus was on the first phase, which is the need analysis. The main objective of this phase is to collect data regarding the need for module development, primarily from the perspective of teachers.

2.2. Population and study sample

The population of this study comprises primary school teachers residing in the Cirebon District, Indonesia. Based on the data obtained from the Indonesian Central Statistics Agency, the population of primary school teachers in Cirebon district totals 8,672 [32]. According to Krejcie and Morgan [33], the required sample size was 368 individuals, which was determined from the total population. However, it is important to clarify that this survey gathered responses from a total of 483 participants who randomly and freely completed the survey distributed by researchers. Because the study specifically targets teachers instructing students from the third to sixth grades of primary school and only includes respondents willing to participate, a selection process was carried out, resulting in 397 teachers meeting the established criteria. This sample size is adequate for the population in Cirebon District.

2.3. Study instrument

Need analysis in this study was conducted using an online survey approach through Google Forms to reach the intended audience. This approach aimed to identify existing issues related to STEM education and project-based learning in primary school, gauge the necessity for the development of STEM project-based learning module, and determine which topics should be prioritized based on teacher feedback. Furthermore, the survey design, in this context quantitatively captured the trends, attitudes, and opinions within a population to assess relationships between various other population variables [34]. For this study, an online survey was used via Google Forms. This approach offered several advantages compared to traditional paper surveys, including being paperless, environmentally friendly, time-efficient, cost-effective, providing accurate collation of answers from the respondents, and being practical in its implementation [35]. The 5 Likert scale of agreement used in this survey questions is stated as 1=strongly disagree; 2=disagree; 3=neither agree; 4=agree and 5=strongly agree.

2.3.1. Validity and reliability instrument

To ensure the authenticity of the results, before the questionnaire is actually used, it is important for researchers to know the validity and reliability of the instrument. In this study, content and language validation were carried out by experts in the field of primary school education, science education, and language. Content validity and language validity can also be classified as rational validity because they result from rational inferences about task conditions that will measure the intended abilities or analysis using logical analysis [36]. Results from validation, all experts agreed on the face validity, content validity, and construct validity of the questionnaire.

Furthermore, a pilot study was conducted to assess the reliability of the instrument and enhance the questionnaire items. In this phase, a pilot study consisting of the participation of 33 primary school teachers was conducted to assess the reliability of the closed-item questionnaire instrument that used a 5-point Likert scale. Range of reliability coefficient or Cronbach alpha values between 0 and 1, with between 0.7 and 0.9 as the optimal values [34]. As presented in Table 1, the Cronbach alpha value for all elements obtained were above 0.7 indicates the questionnaire have high reliability.

It is important to acknowledge that the teachers selected for the pilot study were from primary school in the Depok District, which is not the population of the actual study. However, this was primarily because the participants shared the same characteristics as the study population [37]. These characteristics include the fact that the participants were teachers instructing students from the third to sixth grades of primary school.

Table 1. Cronbach alpha value of the needs analysis instrument

No.	Elements	Cronbach alpha value	No. of items
1.	Problems that exist regarding STEM and project-based learning in primary schools	0.908	16
2.	Information regarding the need to develop the module	0.943	10

2.4. Data analysis

The collected data were descriptively analyzed in order to derive percentage figures, mean values, and standard deviations. Type 1 instruments, aimed to identify existing problems related to STEM education and project-based learning. It also aided the identification of the requirements needed for the development of STEM project-based learning modules. Therefore, closed items seeking to determine the most challenging topics for students and those with the most misconceptions were analyzed in terms of percentages. Table 2 presents the interpretation of mean values, adapted from Wiersma [38].

Table 2. Interpretation of the mean value

Mean value	Interpretation
1.00-2.33	Low
2.34-3.67	Medium
3.68-5.00	High

3. RESULTS AND DISCUSSION

Based on the results of need analysis, the teacher perceptions including: i) identifying current challenges related to STEM and project-based learning in primary school; ii) assessing the necessity for developing STEM project-based learning modules; and iii) pinpointing specific topics that require development based on teacher perceptions are discussed.

3.1. Teacher perceptions of existing problems related to STEM and project-based learning

Before embarking on the development of STEM project-based learning modules aimed at enhancing scientific literacy and critical thinking in primary school, it is essential to understand the challenges teachers encounter when implementing both STEM and project-based learning. In this regard, Table 3 presents the computed average percentage, mean value, and standard deviation derived from analysis of data obtained through the questionnaire which addressed existing problems associated with STEM project-based learning. As a step towards identifying the development requirements of STEM project-based learning module, this study aimed to understand teacher perceptions regarding existing issues related to STEM and project-based learning.

Table 3. Teacher perceptions analysis of existing problems related to STEM and project-based learning

Items	Disagree (%)	Agree (%)	Mean	Standard deviation
Problems in project-based learning				
1. Limited learning time	18.39	81.61	3.43	1.03
2. Limitation of teaching materials that contain project-based learning	16.37	83.63	3.45	1.02
3. Difficulty result the right project-based learning strategy	12.59	87.41	3.46	0.92
4. Difficulty choosing the right project	15.62	84.38	3.42	0.96
5. Limited teacher experience related to the implementation of project-based learning	16.12	83.88	3.47	1.02
6. Limited teacher knowledge of project-based approach	18.39	81.61	3.41	1.05
7. Lack of motivation of students	32.49	67.51	3.05	1.15
8. Lack of school support	29.97	70.03	3.13	1.08
Problems in STEM education				
1. Limited learning time	18.14	81.86	3.42	1.00
2. Limitation of teaching materials that contain STEM	13.60	86.40	3.54	1.00
3. Difficulty result the right STEM strategy	13.35	86.65	3.51	0.94
4. Difficulty choosing the right STEM project	11.59	88.41	3.52	0.94
5. Limited teacher experience related to the implementation of STEM learning	12.34	87.66	3.49	0.94
6. Limited teacher knowledge about STEM approach	16.37	83.63	3.42	0.98
7. Lack of motivation of students	26.95	73.05	3.17	1.10
8. Lack of school support	25.69	74.31	3.19	1.06
Average	18.62	81.38	3.38	1.01

Note: the term "disagree" combines responses of "strongly disagree" and "disagree," while "agree" consists of "somewhat agree," "agree," and "strongly agree

As presented in Table 3, the data interpretation yielded a mean value of 3.38 and a standard deviation of 1.01. This indicated that the matter fell within a moderate level of concern. Therefore, the item with the highest mean score among the existing problems associated with project-based learning was observed to be the limited teacher experience in implementing project-based learning (M=3.47, SD=1.02), followed closely by the challenges associated with result suitable project-based learning strategies (M=3.46, SD=0.92), and a lack of teaching materials that incorporate this form of learning (M=3.45, SD=1.02). These

values indicated that a majority of primary school teachers perceive teacher experience, the difficulty in result appropriate project-based learning strategies, and the absence of project-based teaching materials as primary challenges faced when implementing project-based learning.

In this regard, it was also observed that the items with the highest mean scores were related to the lack of teaching materials (M=3.54, SD=1.00), the difficulty in selecting appropriate project (M=3.52, SD=0.94), and the challenges in result effective learning strategies (M=3.51, SD=0.94), all of which are related to STEM. Therefore, these results show that the majority of primary school teachers perceive the lack of teaching materials featuring STEM, the difficulties in project selection within the context of the field under study, and the challenges in locating effective learning strategies in the same regard as primary obstacles when it comes to STEM education. Table 3 shows the lack of teaching materials and examples of learning strategies related to STEM and project-based learning are the main obstacles faced by teachers in schools. Teachers in the field need examples of STEM content and forms of learning that can be applied in their classrooms. Even though a teacher must have comprehensive and holistic knowledge, especially in terms of learning materials [39]. Through modules it can help teachers and students obtain information about the material and also steps in learning. This is because the module has the most complete components compared to other learning materials, such as worksheets, study guides, basic competencies, activities, support information, worksheets, assignments and assessments [40].

STEM education is a unique approach that involves science, technology, engineering, and mathematics in its application. Although teacher have very similar backgrounds, they may interpret the purpose of learning and teaching engineering design in STEM education differently. This problem can be overcome by encourage teacher to view the use of engineering design as knowledge construction dan providing teacher with strategies to deal with problem [41].

3.2. Teacher perceptions of the development need of STEM- project-based learning modules

In this section, the study examined the perceptions of primary school teachers regarding the necessity of developing STEM project-based learning module. Table 4 provides an overview of the average percentage, mean value, and standard deviation derived from analysis of data collected through the questionnaire, with a focus on the goals of modules development. The collective teacher perspective in this section indicated a high level of agreement, with an average value of 4.10 and a standard deviation of 0.77, signifying strong consensus. From the mean values, it can be observed that primary school teachers in Cirebon strongly agreed on several key points. These educators believe that students require STEM knowledge (M=4.12, SD=0.87), and integrating this concept into the learning process, specifically with project-based learning strategy, is appropriate (M=4.04, SD=0.76). Furthermore, the teachers expressed need for the implementation of STEM project-based learning modules to facilitate and enhance scientific literacy (M=4.14, SD=0.73), as well as foster critical thinking skills among students (M=4.12, SD=0.75). These results underscored the demand of the observed primary school teachers for STEM project-based learning modules geared towards enhancing the level of scientific literacy and critical thinking abilities inherent in students.

Table 4. Teacher perceptions analysis about development need of STEM project-based learning module

Items	Disagree (%)	Agree (%)	Mean	Standard deviation
1. Students need to be trained in STEM knowledge.	4.03	95.97	4.12	0.87
2. Need to integrate STEM into learning in primary school.	1.76	98.24	4.13	0.72
3. STEM learning module need to be developed.	2.52	97.48	4.08	0.77
4. Project-based learning approach need to be applied in science learning in primary school.	3.02	96.98	4.09	0.80
5. It is necessary to develop project-based learning modules in science learning in primary school.	3.27	96.73	4.11	0.78
6. Integrating STEM into learning will be appropriate if implemented with project-based learning strategy.	2.52	97.48	4.04	0.76
7. It is necessary to develop STEM project-based learning module for scientific literacy of primary school students.	2.02	97.98	4.14	0.73
8. It is necessary to develop STEM project-based learning module for critical thinking of primary school students.	2.02	97.98	4.12	0.75
9. The development of STEM project-based learning module in learning can help improve the effectiveness of the application of scientific literacy by science teachers in primary school in the future.	3.02	96.98	4.08	0.80
10. The development of STEM project-based learning module in learning can help improve the effectiveness of the application of critical thinking by science teachers in primary school in the future.	2.52	97.48	4.07	0.77
Average	2.67	97.33	4.10	0.77

Note: the term "disagree" combines responses of "strongly disagree" and "disagree," while "agree" consists of "somewhat agree," "agree," and "strongly agree."

The use of modules in learning can be integrated with certain learning approaches, in this study STEM education based on a project approach is used in developing modules for primary school teachers that can facilitate students to be actively involved in learning. The project-based learning approach suitable if integrated with the STEM approach, this is because project-based learning or STEM is expected to produce output in the form of products. In implementing STEM project-based learning, students are conditioned in meaningful learning situations to understand a concept and explore through project activities, so that students are actively involved and can stimulate students to think at a higher level and teachers have the opportunity to teach students and then make changes to better align their teaching with the desired outcomes [42].

In accordance with the views of teachers, the STEM project-based learning module has the potential to improve skills needed in the 21st century such scientific literacy. The STEM learning approach integrated with project-based learning can improve students' scientific literacy skills [43]. This is because STEM project-based learning integrated with scientific literacy engages students in real-life problem-solving activities and engages students in investigations. Learning strategies based on STEM education approaches also have the potential to improve students' critical thinking abilities [44], [45]. This research can give implications to policy makers and education practitioners in order to get an overview of the development process and form of STEM learning modules based on the project approach which is an important component that needs to be included in the learning curriculum to facilitate the development of relevant skills that will enable students to stand out in the 21st century.

3.3. Teacher perceptions of topics that need to be developed

The questionnaire in this section was used to gather the opinions of teachers regarding both the most difficult and most misconception topics among students from the third to sixth grades in the fields of science. Table 5 presents the topics considered the most difficult and those causing the most misconceptions according to the perspectives of the teachers. It presents the results obtained from questionnaire, which assessed both the most difficult and the largely misconception topics, based on the perspective of the teachers. The results in Table 5 showed that, the most difficult topic is the human body organ systems, with a percentage value of 21.16%. In contrast, the topic of matter and change exhibited the highest percentage of misconceptions, at 21.41%.

Table 5. Analysis of teacher perceptions of topics that need to be developed

No.	Topic	The most difficult topic		The topic that gives rise to the most misconceptions	
		Amount	Percentage (%)	Amount	Percentage (%)
1.	The five senses	7	1.76	11	2.77
2.	The life cycle of living things	13	3.27	13	3.27
3.	Conservation of natural resources and living creatures	22	5.54	27	6.80
4.	Substances and their changes	71	17.88	85	21.41
5.	Energy (heat and electricity)	55	13.85	39	9.82
6.	Force and movement	30	7.56	44	11.08
7.	Water cycle	20	5.04	19	4.79
8.	Human body organ systems	84	21.16	67	16.88
9.	Ecosystem	17	4.28	10	2.52
10.	Light and sound	27	6.80	26	6.55
11.	Alternative energy	21	5.29	25	6.30
12.	Solar system	30	7.56	31	7.81
	Total	397	100	397	100

Previous study has indicated that the human body organ system is a complex concept for students to grasp. While the structure and function of these organs can be effectively described by the learners, there is often a struggle to establish the connections between their structure and function [46]. Students tend to recognize specific body parts but face difficulties in comprehending the holistic functioning of the system [47]. Similarly, the topic of matter and its changes has been considered challenging and prone to misconceptions [48]. Students, in this context, encounter difficulties in grasping both microscopic and macroscopic concepts related to matter [49], often using irrelevant concepts to explain observed phenomena [50]. In this regard, it is essential to clarify that for primary school students, the topic of matter and its changes can be abstract and, consequently, challenging to comprehend [51]. For the primary school students, abstract topics can already be taught through activities that suit their cognitive development. By presenting a context that is close to students' lives, it can make it easier for students to learn the abstract concepts. Through STEM education based on a project approach, students learn to solve problems in their daily lives, including engaging with abstract scientific concepts to solve the problems they face [52], [53].

4. CONCLUSION

In conclusion, the challenges faced by teachers in the field of STEM education and project-based learning include the scarcity of teaching materials and the difficulty of identifying suitable learning strategies. However, it is essential to acknowledge that the observed primary school teachers expressed need for STEM project-based learning modules to foster the development of skills in students that are relevant to the 21st century, particularly scientific literacy and critical thinking. According to data gathered on teacher perceptions, the most challenging topic is the human body organ systems, with a percentage value of 21.16%, while the topic of matter and change is associated with the highest rate of misconceptions, at 21.41%. In summary, the obtained results underscored the necessity for the development of STEM project-based learning modules at primary school level. Lastly, this study recommended that further study should explore the development of STEM modules based on project-based learning approach, to cater to a range of topics.

REFERENCES

[1] A. Burrows, M. Lockwood, M. Borowczak, E. Janak, and B. Barber, "Integrated STEM: focus on informal education and community collaboration through engineering," *Education Sciences*, vol. 8, no. 1, p. 4, Jan. 2018, doi: 10.3390/educsci8010004.

[2] W. Park, J.-Y. Wu, and S. Erduran, "The nature of STEM disciplines in the science education standards documents from the USA, Korea and Taiwan," *Science & Education*, vol. 29, no. 4, pp. 899–927, Aug. 2020, doi: 10.1007/s11191-020-00139-1.

[3] A. Z. Ilma, I. Wilujeng, A. Widowati, M. Nurtanto, and N. Kholifah, "A systematic literature review of STEM education in Indonesia (2016-2021): contribution to improving skills in 21st century learning," *Pegem Journal of Education and Instruction*, vol. 13, no. 2, pp. 134–146, Jan. 2023, doi: 10.47750/pegegog.13.02.17.

[4] M. M. Fausan, H. Susilo, A. Gofur, S. Sueb, and F. D. Yusop, "The scientific literacy performance of gifted young scientist candidates in the digital age," *Jurnal Cakrawala Pendidikan*, vol. 40, no. 2, pp. 467–498, 2021, doi: 10.21831/cp.v40i2.39434.

[5] S. J. Seage and M. Türegün, "The effects of blended learning on STEM achievement of elementary school students," *International Journal of Research in Education and Science*, vol. 6, no. 1, pp. 133–140, Nov. 2019, doi: 10.46328/ijres.v6i1.728.

[6] E. Sujarwanto, Madlazim, and I. G. M. Sanjaya, "A conceptual framework of STEM education based on the Indonesian Curriculum," *Journal of Physics: Conference Series*, vol. 1760, no. 1, p. 012022, Jan. 2021, doi: 10.1088/1742-6596/1760/1/012022.

[7] N. M. Siew and N. Ambo, "The scientific creativity of fifth graders in a stem project-based cooperative learning approach," *Problems of Education in the 21st Century*, vol. 78, no. 4, pp. 627–643, Aug. 2020, doi: 10.33225/pec/20.78.627.

[8] E. Viro, D. Lehtonen, J. Joutsenlahti, and V. Tahvanainen, "Teachers' perspectives on project-based learning in mathematics and science," *European Journal of Science and Mathematics Education*, vol. 8, no. 1, pp. 12–31, Jan. 2020, doi: 10.30935/scimath/9544.

[9] S. L. Kim and D. Kim, "English learners' science-literacy practice through explicit writing instruction in invention-based learning," *International Journal of Educational Research Open*, vol. 2, p. 100029, 2021, doi: 10.1016/j.ijedro.2020.100029.

[10] N. Wijayati, W. Sumarni, and S. Supanti, "Improving student creative thinking skills through project based learning," in *UNNES International Conference on Research Innovation and Commercialization 2018, KnE Social Sciences*, Jul. 2019, pp. 408–421, doi: 10.18502/kss.v3i18.4732.

[11] G. W. Hodges, K. Flanagan, J. Lee, A. Cohen, S. Krishnan, and C. Ward, "A quasi-experimental study comparing learning gains associated with serious educational gameplay and hands-on science in elementary classrooms," *Journal of Research in Science Teaching*, vol. 57, no. 9, pp. 1460–1489, Nov. 2020, doi: 10.1002/tea.21661.

[12] N. Sulaeman, S. Efwinda, and P. D. A. Putra, "Teacher readiness in STEM education: voices of Indonesian physics teachers," *Journal of Technology and Science Education (JOTSE)*, vol. 12, no. 1, pp. 68–82, Feb. 2022, doi: 10.3926/jotse.1191.

[13] Y. Wahyu, I. W. Suastra, I. W. Sadia, and N. K. Suarni, "The effectiveness of mobile augmented reality assisted STEM-based learning on scientific literacy and students' achievement," *International Journal of Instruction*, vol. 13, no. 3, pp. 343–356, Jul. 2020, doi: 10.29333/iji.2020.13324a.

[14] N. Anand and B. Dogan, "Impact of informal learning environments on STEM education—Views of elementary students and their parents," *School Science and Mathematics*, vol. 121, no. 6, pp. 369–377, Oct. 2021, doi: 10.1111/ssm.12490.

[15] Y. E. Y. Siregar, R. Rachmadtullah, N. Pohan, Rasmitadila, and M. Zulela, "The impacts of science, technology, engineering, and mathematics (STEM) on critical thinking in elementary school," *Journal of Physics: Conference Series*, vol. 1175, p. 012156, Mar. 2019, doi: 10.1088/1742-6596/1175/1/012156.

[16] M. Scriven and R. Paul, "Defining critical thinking," in *8th Annual International Conference on Critical Thinking and Education Reform*, 1987.

[17] R. J. Schlegel, S. L. Chu, K. Chen, E. Deuermeyer, A. G. Christy, and F. Quek, "Making in the classroom: longitudinal evidence of increases in self-efficacy and STEM possible selves over time," *Computers & Education*, vol. 142, p. 103637, Dec. 2019, doi: 10.1016/j.compedu.2019.103637.

[18] D. J. M. Velazco, E. M. F. Hinostroza, J. E. S. Moreno, J. F. P. Cerda, and M. V. S. Barros, "Attitudes of Ecuadorian secondary school teaching staff towards online STEM development in 2022," *International Journal of Learning, Teaching and Educational Research*, vol. 21, no. 7, pp. 59–81, Jul. 2022, doi: 10.26803/ijlter.21.7.4.

[19] A. D. M. Hawari and A. I. M. Noor, "Project based learning pedagogical design in STEAM art education," *Asian Journal of University Education*, vol. 16, no. 3, pp. 102–111, Oct. 2020, doi: 10.24191/ajue.v16i3.11072.

[20] H. Hussin, P. Y. Jiea, R. N. R. Rosly, and S. R. Omar, "Integrated 21st century science, technology, engineering, mathematics (STEM) education through robotics project-based learning," *Humanities & Social Sciences Reviews*, vol. 7, no. 2, pp. 204–211, Mar. 2019, doi: 10.18510/hssr.2019.7222.

[21] A. Utami, D. Rochintaniawati, and I. R. Suwarma, "Enhancement of STEM literacy on knowledge aspect after implementing science, technology, engineering and mathematics (STEM)-based instructional module," *Journal of Physics: Conference Series*, vol. 1521, no. 4, p. 042048, Mar. 2020, doi: 10.1088/1742-6596/1521/4/042048.

[22] A. Sellami, M. Ammar, and Z. Ahmad, "Exploring teachers' perceptions of the barriers to teaching STEM in high schools in Qatar," *Sustainability*, vol. 14, no. 22, p. 15192, Nov. 2022, doi: 10.3390/su142215192.

[23] E. Setyaningsih, C. N. C. Ahmad, M. Adnan, and S. Anif, "Literature review: development of STEM learning in Indonesia based on variation of subjects, media, and strategy of study from 2015 to 2019," *Review of International Geographical Education (RIGEO)*, vol. 11, no. 4, pp. 1023–1033, 2021.

[24] D. Glaroudis, A. Iossifides, N. Spyropoulou, I. D. Zaharakis, and A. D. Kameas, "STEM learning and career orientation via IoT hands-on activities in secondary education," in *2019 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)*, Mar. 2019, pp. 480–485, doi: 10.1109/PERCOMW.2019.8730759.
[25] J. L. G. Castellanos *et al.*, "Chemistry in our community: strategies and logistics implemented to provide hands-on activities to K–12 students, teachers, and families," *Journal of Chemical Education*, vol. 98, no. 4, pp. 1266–1274, Apr. 2021, doi: 10.1021/acs.jchemed.0c01120.
[26] B. Li, X. Jia, Y. Chi, X. Liu, and B. Jia, "Project-based learning in a collaborative group can enhance student skill and ability in the biochemical laboratory: a case study," *Journal of Biological Education*, vol. 54, no. 4, pp. 404–418, Aug. 2020, doi: 10.1080/00219266.2019.1600570.
[27] M. Baran, M. Baran, F. Karakoyun, and A. Maskan, "The influence of project-based STEM (PjbL-STEM) applications on the development of 21st century skills," *Turkish Journal of Science Education*, vol. 18, no. 4, pp. 798–815, Dec. 2021, doi: 10.36681/tused.2021.104.
[28] H. Azis, "Effectiveness of e-module based on integrated project based learning model ethno-STEM Approach on smartphones for student senior high school grade XI," *International Journal of Progressive Sciences and Technologies (IJPSAT)*, vol. 30, no. 1, pp. 273–279, 2021.
[29] A. N. Pane, D. Andra, and I. W. Distrik, "The development physics e-module based PBL–integrated STEM to improve higher-order thinking skills on static fluid material," *Journal of Physics: Conference Series*, vol. 1796, no. 1, p. 012086, Feb. 2021, doi: 10.1088/1742-6596/1796/1/012086.
[30] R. C. Richey and J. D. Klein, *Design and Development Research*, 1st ed. New York: Routledge, 2007, doi: 10.4324/9780203826034.
[31] K. Gengatharan, A. bin Rahmat, and S. D. Krishnan, "Need-analysis on importance of health education assessment module for lower primary teachers in classroom-based assessment," *Universal Journal of Educational Research*, vol. 8, no. 8, pp. 3355–3359, Aug. 2020, doi: 10.13189/ujer.2020.080807.
[32] "Number of elementary school teachers 2020-2022 (in Indonesian)," Badan Pusat Statistik Provinsi Jawa Barat (Statistics of Jawa Barat), [Online]. Available: https://jabar.bps.go.id/indicator/28/148/1/jumlah-guru-sekolah-dasar.html (accessed: Jun. 06, 2023).
[33] R. V. Krejcie and D. W. Morgan, "Determining sample size for research activities," *Educational and Psychological Measurement*, vol. 30, no. 3, pp. 607–610, Sep. 1970, doi: 10.1177/001316447003000308.
[34] J. W. Creswell and J. D. Creswell, *Research design: qualitative, quantitative, and mixed method approach*, 5th ed. SAGE Publications, Inc., 2018.
[35] N. Rohmah, H. Mohamad, and M. Shofiyuddin, "Implementation of Google Forms in ECE to face digital era," in *Proceedings of the 4th International Conference on Early Childhood Education. Semarang Early Childhood Research and Education Talks (SECRET 2018)*, Paris, France: Atlantis Press, 2018, pp. 177–180, doi: 10.2991/secret-18.2018.28.
[36] R. L. Ebel and D. A. Frisbie, *Frisbie, essentials of educational measurement*, 5th ed. New Delhi: Prentice-Hall, 1991.
[37] Y. P. Chua, *Mastering research methods*, 2nd ed. McGraw-Hill Education, 2016.
[38] W. Wiersma, *Research methods in education: an introduction*. Needham Heights: Allyn & Bacon, 2000.
[39] B. Wijayanto, S. Sumarmi, D. H. Utomo, B. Handoyo, and M. Aliman, "Development of e-module based on geospatial technology to improve TPACK competencies of geography pre-service teacher: a needs analysis review," *TEM Journal*, vol. 12, no. 2, pp. 1190–1200, May 2023, doi: 10.18421/TEM122-65.
[40] Yerimadesi, Y. Kiram, Lufri, and Festiyed, "Development of guided discovery learning based module on colloidal system topic for senior high school," *Journal of Physics: Conference Series*, vol. 1116, p. 042044, Dec. 2018, doi: 10.1088/1742-6596/1116/4/042044.
[41] M. A. Shahat, S. M. Al-Balushi, and M. Al-Amri, "Measuring preservice science teachers' performance on engineering design process tasks: implications for fostering STEM education," *Arab Gulf Journal of Scientific Research*, vol. 42, no. 2, pp. 259–279, Mar. 2023, doi: 10.1108/AGJSR-12-2022-0277.
[42] G. Reynders, J. Lantz, S. M. Ruder, C. L. Stanford, and R. S. Cole, "Rubrics to assess critical thinking and information processing in undergraduate STEM courses," *International Journal of STEM Education*, vol. 7, no. 1, p. 9, Dec. 2020, doi: 10.1186/s40594-020-00208-5.
[43] A. Adriyawati, E. Utomo, Y. Rahmawati, and A. Mardiah, "STEAM-project-based learning integration to improve elementary school students' scientific literacy on alternative energy learning," *Universal Journal of Educational Research*, vol. 8, no. 5, pp. 1863–1873, May 2020, doi: 10.13189/ujer.2020.080523.
[44] R. Ali, J. Bhadra, N. Siby, Z. Ahmad, and N. J. Al-Thani, "A STEM model to engage students in sustainable science education through sports: a case study in Qatar," *Sustainability*, vol. 13, no. 6, p. 3483, Mar. 2021, doi: 10.3390/su13063483.
[45] S. Ardianti, D. Sulisworo, Y. Pramudya, and W. Raharjo, "The impact of the use of STEM education approach on the blended learning to improve student's critical thinking skills," *Universal Journal of Educational Research*, vol. 8, no. 3B, pp. 24–32, Mar. 2020, doi: 10.13189/ujer.2020.081503.
[46] K. P. Carter and L. B. Prevost, "Formative assessment and student understanding of structure-function," *Advances in Physiology Education*, vol. 47, no. 3, pp. 615–624, Sep. 2023, doi: 10.1152/advan.00215.2022.
[47] M. Arık and M. S. Topçu, "Computational thinking integration into science classrooms: example of digestive system," *Journal of Science Education and Technology*, vol. 31, no. 1, pp. 99–115, Feb. 2022, doi: 10.1007/s10956-021-09934-z.
[48] R. Abdullah, M. Pikoli, and N. Suleman, "Analysis of scientific argument of vocational high school students on the topic of substance change," *Journal of Physics: Conference Series*, vol. 1760, no. 1, p. 012008, Jan. 2021, doi: 10.1088/1742-6596/1760/1/012008.
[49] J. Lee, B. Lee, and T. Noh, "A comparison of middle school students' macroscopic and microscopic conceptions related to the properties of substances," *Journal of the Korean Chemical Society*, vol. 62, no. 3, pp. 243–352, 2018.
[50] E. Nursa'adah, L. Liliasari, A. Mudzakir, and H. D. Barke, "The model of educational reconstruction: students' conceptual knowledge on solid state chemistry domain," *Jurnal Pendidikan IPA Indonesia*, vol. 7, no. 2, pp. 193–203, Jul. 2018, doi: 10.15294/jpii.v7i2.14297.
[51] A. Ewais and O. de Troyer, "A usability and acceptance evaluation of the use of augmented reality for learning atoms and molecules reaction by primary school female students in Palestine," *Journal of Educational Computing Research*, vol. 57, no. 7, pp. 1643–1670, Dec. 2019, doi: 10.1177/0735633119855609.
[52] C. Bujanda and N. Anderson, "Teaching the central dogma through an inquiry-based project using GFP," *The American Biology Teacher*, vol. 84, no. 1, pp. 33–37, Jan. 2022, doi: 10.1525/abt.2022.84.1.33.
[53] D. Tomblin and N. Mogul, "STS Postures: responsible innovation and research in undergraduate STEM education," *Journal of Responsible Innovation*, vol. 7, no. sup1, pp. 117–127, Dec. 2020, doi: 10.1080/23299460.2020.1839230.

BIOGRAPHIES OF AUTHORS

Riski Septiadevana is a Ph.D. student at Primary School Education, Faculty of Human Development, Universiti Pendidikan Sultan Idris, Malaysia and lecturer at primary teacher education, Sekolah Tinggi Pendidikan Holistik Berbasis Karakter (STPHBK), Indonesia. Her research interest on science education and elementary education. She can be contacted at email: devana.kiky@gmail.com.

Norazilawati Abdullah is an Associate Professor, Deputy Director (Research and Inovation) at National Child Development Research Centre (NCDRC), and also senior lecturer at Faculty of Human and Development, Universiti Pendidikan Sultan Idris, Malaysia. Her publications and research interest on science education, pedagogy, curriculum, technology and assessment in education. She can be contacted at email: nora@fpm.upsi.edu.my.