Momentum: Physics Education Journal
8 (1), 2024, 84-94
Available at: ejournal.unikama.ac.id/index.php/momentum
ISSN 2548-9127(print) | 2548-9135 (online)

Analysis of physics learning in elementary schools and the need for professional development: Is STEM education training necessary for elementary school teachers?

Didit Ardianto*, Tustiyana Windiyani, Irma Rahma Suwarma, Karmilasari, Najla Nurul

Pakuan University, 1 Pakuan Street, Bogor, Indonesia
e-mail: diditardianto@unpak.ac.id
* Corresponding Author.

Received: 5 September 2023; Revised: 5 October 2023; Accepted: 23 October 2023

Abstract: This study aims to explore pedagogical approaches and students' engagement during STEM teaching. As many as 215 elementary school teachers in West Java were involved in this research. Those involved consisted of 161 women and 49 men. The majority of teachers have an elementary school teacher education background (87%), 7% have other educational backgrounds (Science Education/Mathematics Education/Social Education/Language Education), and the remaining 6% are in the sciences. The instrument used in this study was a closed questionnaire with 20 items from a Likert scale survey. The results of the study show that 50% of elementary school teachers very rarely use experimental approaches and problem-based learning when teaching STEM content. More than 60% of teachers also very rarely use the inquiry approach in teaching the four contents. The approach that is often used by teachers in teaching STEM is a collaborative and integrated approach. In addition, the survey results also show that more than 50% of students are very rarely involved in inquiry and engineering practice activities when learning about STEM content. The analysis of professional development needs showed that the majority of elementary school teachers have never received a professional development program regarding STEM education. In fact, the majority of teachers have a positive attitude towards the coaching program, which has an impact on increasing their competence. Apart from that, the results of this research also show that there is a lack of external support (from universities, educational practitioners, and researchers) for teachers in coaching programs. These findings provide evidence that teachers still need to receive training on pedagogical approaches that are relevant to integrated STEM education. The existence of training on STEM education is expected to improve the quality of STEM learning in the classroom. Thus, students' involvement in scientific and engineering practice when learning STEM becomes more dominant.
Keywords: teacher professional development; STEM Education; physic learning

How to Cite: Ardianto, D., Windiyani, T., Suwarma, I. R., Karmilasari, K., & Nurul, N. (2023). Analysis of physics learning in elementary schools and the need for professional development: Is STEM education training necessary for elementary school teachers?. *Momentum: Physics Education Journal*, *8*(1), 84-94. https://doi.org/10.21067/mpej.v8i1.9105

Introduction

The National Academy of Sciences reported that future career options will require individuals skilled in problem-solving, quantitative reasoning, and modeling, as well as effective communication and collaboration (National Research Council, 2012). In 2021, the Employment Data Management Division indicated that unskilled labor still largely dominates Indonesia's workforce, according to data from the Central Statistics Agency. Furthermore, a significant portion of the population (30%) is

DOI: 10.21067/mpej.v8i1.9105

engaged in production work, transportation equipment operation, and rough labor. Only about 7% of the Indonesian population works in professional, technical, and related occupations (Directorate of Population and Labor Statistics, 2022). This data suggests that STEM literacy among the Indonesian workforce is still low. Individuals' literate in STEM are considered capable of identifying, integrating, and implementing these four disciplines to solve real-world problems.

According to the PISA survey results from 2012 to 2018, the average scores for science, mathematics, and language literacy among Indonesian students remain very low. In 2012, the scores for mathematics, language, and science literacy were 375, 396, and 382, respectively (OECD, 2014). In 2015, the scores for science, language, and mathematics literacy were 403, 397, and 386, respectively (OECD, 2018). Similarly, in 2018, the scores for science, language, and mathematics literacy were 396, 371, and 379 (OECD, 2019). These data indicate that the science, mathematics, and language literacy of Indonesian students are still unsatisfactory, as they fall below the average scores of all participating countries. According to the OECD, 71% of students do not reach the minimum level of mathematical competence. In the field of science, only 35% of Indonesian students are still at competency level 1a, and 17% are at a lower level. This fact suggests that students have limited scientific knowledge that can only be applied in a few familiar situations.

Science, language, and mathematics literacy are highly interconnected with STEM literacy. Science literacy can be defined as the ability to read and write about science and technology. The ability to think systematically, logically, and rationally, which constitutes a part of mathematical literacy, significantly influences individual science literacy. Meanwhile, language literacy is necessary for individuals to communicate their thoughts in real-life contexts. An individual proficient in science, language, and mathematics typically employs critical thinking to contemplate discovered phenomena in a logical and systematic manner.

All three literacies are also closely related to engineering literacy. Engineering literacy can be defined as the ability of an individual to systematically and creatively apply mathematical and scientific principles to practical activities such as designing, building, and operating structures, machinery, processes, and systems economically and efficiently.

This description indicates that science, technology, engineering, and mathematics literacy are interwoven with each other. Therefore, STEM literacy is crucial as a benchmark for student achievement in schools. Based on the survey results of STEM literacy among students in the cities of Bogor and Cianjur Regency, the obtained results were less than satisfactory. The research conducted in 2021 showed that students' STEM literacy still needs improvement. The data on students' STEM literacy achievement is still quite low, with an average of 32% across all domains (Ardianto et al., 2021). Furthermore, the research results also indicate that the average interest scores of elementary and junior high school students in the fields of science, technology, engineering, and mathematics are 2.5 out of a maximum score of 5.

The low level of STEM literacy among students is a pressing issue that needs to be promptly addressed, as it will impact students' interest in these four disciplines. Furthermore, if this issue is not resolved, students may face difficulties coping with future job and economic challenges. Individuals with limited STEM literacy also tend to be less creative in addressing real-life problems. According to several studies, the low level of STEM literacy among students can be attributed to various factors, including the low quality of STEM education in schools, students' limited access to engineering and technology disciplines, and the lack of guidance from adults with knowledge or careers in STEM fields (Guzey et al., 2014; Ismail, 2022; Tyler-Wood et al., 2010). These studies indicate that the quality of teaching and learning, as well as the role of teachers in schools, significantly influence students' STEM literacy achievement. Therefore, conducting a study on the analysis of teaching and the professionalism of teachers, particularly in elementary schools, is an initial step that needs to be taken. It is hoped that the findings of this research will serve as a reference for determining appropriate solutions to enhance students' STEM literacy.

Literature Review

STEM Education

Science, Technology, Engineering, and Mathematics (STEM) are disciplines highly essential for various future occupations. Furthermore, these four disciplines play a crucial role in enhancing a nation's economic growth (Tyler-Wood et al., 2010). Students need to be equipped with STEM capabilities so that they can address globalization and economic challenges (Luo et al., 2019). Therefore, following the above-mentioned survey results, there is a need for the development of STEM education programs for students (Firman, 2015). STEM-based education has been proven effective in enhancing their knowledge, skills, and disposition towards STEM (National Research Council, 2012; Wagner et al., 2017). Additionally, several studies have shown that STEM-based science education contributes positively to students' interest in STEM (Guzey et al., 2014; Sadler et al., 2012; Sjaastad, 2013). These studies indicate that measuring students' interest can serve as crucial evidence for improving the quality of STEM teaching and learning.

STEM-Based Teacher Professional Development

The study of the professional development of STEM teachers has become an intriguing issue in recent times. Therefore, researchers conducted a systematic literature review (SLR) to explore studies pertaining to this topic. The process of selecting relevant studies was carried out on electronic databases, namely: (1) ERIK; (3) Springer; and (4) Scopus. The keywords used were: ("STEM" OR "STEM Professional Development" OR "STEM-TEACHER"). The search was limited to research conducted from 2013 to 2023 (the last 10 years). Studies for analysis had to report the results of professional development interventions in STEM education and include a description of the development program. Articles lacking these details were not included in the analysis. There were no restrictions on academic disciplines, but the content of professional development had to be in the STEM field.

The results of the literature review indicate that research on the professional development of STEM teachers has been conducted in various countries. The United States has the highest number of studies in this area (N = 17), while Australia, England, and Korea each have one study (Chai, 2019). Some of the conducted studies show that STEM professional development has proven to enhance teachers' attitudes toward STEM teaching practices (Salami et al., 2017), improve teachers' knowledge structure regarding engineering concepts (Cavlazoglu & Stuessy, 2017), and foster confidence, self-efficacy, and teachers' perceptions towards STEM (Nadelson et al., 2013).

Past research reveals diverse methods for STEM professional development, including workshops, seminars, reflective practices, video analysis, and collaborative approaches (Cavlazoglu & Stuessy, 2017; Salami et al., 2017; Brown & Bogiages, 2019; Radloff & Guzey, 2017; Richmond et al., 2017). These diverse forms of professional development emphasize the attainment of engineering knowledge (Faber et al., 2014; Fore et al., 2015). The majority of STEM professional development programs are conducted for secondary school teachers, with only three studies conducted specifically for elementary school teachers in the United States (Nadelson et al., 2013; Parker et al., 2015; Radloff & Guzey, 2017). In the context of Southeast Asia, there is only one study that examines the preparation of STEM teaching practices in secondary schools through collaboration among scientists, teachers, and students (Ismail, 2022). Meanwhile, at the regional level, a science teacher professional development program was conducted in 2018, particularly in Bogor City, focusing solely on the science literacy skills of junior high school students (Rubini et al., 2018).

Based on the analysis of several previous studies, it is evident that there has been no specific STEM professional development program for elementary school teachers, particularly in the Southeast Asian context. Furthermore, the existing development programs only involve academics such as scientists, universities, and schools. Therefore, there is a need for research on the requirements for developing STEM professional competence among elementary school teachers.

Method

Design

This survey aims to analyze the pedagogical approaches employed by teachers and student engagement during the physics learning process in elementary schools. Additionally, the study examines the need for STEM professional development for elementary school teachers. The survey was conducted in a cross-sectional manner, with data collected over a two-week period at the end of July 2023.

Subjects

This study involved elementary school teachers in the city of Bogor, with a total population of 3201 individuals. A total of 215 elementary school teachers in Bogor were randomly selected, consisting of 161 females and 49 males. Of the selected group, 28.4% were aged 25–34, 28.8% were aged 35–44, 25.1% were aged 45–54, 11.6% were aged 55–64, and 6% were over 64 years old. The majority of the elementary school teachers participating in this survey had a background in elementary education (87%), 7% had a background in other fields (science/mathematics/Social studies/language), and the remaining 6% had a background in pure sciences. The teaching experience of the participating teachers varied. About 27% had been teaching for 16–20 years, 21.4% for 11–15 years, 18.1% for 6–10 years, 16.3% for over 21 years, and the remaining 17.2% had been teaching for less than 5 years. In a week, 54% of the teachers taught between 20 and 38 sessions, 25.4% taught between 10 and 20 sessions, 16.4% taught less than 10 sessions, and the remaining 4.2% taught more than 38 sessions.

Instruments

The instrument used in this study was a closed-ended questionnaire grouped into four sections. The first part of the questionnaire aimed to gather demographic information from the research subjects, including gender, age, educational background, years of teaching experience, and the number of teaching sessions. In this first section, the questionnaire consisted of six closed-ended questions. The second part of the questionnaire aimed to gather information about the teaching practices in the classroom, including the pedagogical approaches used by teachers and student engagement. This second section comprised 19 statements on a Likert scale, with options ranging from 'never', 'sometimes', 'often', to 'always'. The third part of the questionnaire aimed to gather information about the professional development needs of elementary school teachers. This third section consisted of eight questions specifically addressing: the types of professional development support, institutional support for professional development, and the duration of professional development. Before distribution, the questionnaire was validated by five experts in the field of education. The results of the expert validation were then analyzed quantitatively using content validity ratio (CVR) values. Based on the CVR analysis, all developed items were deemed valid and ready for testing.

Data Collection and Analysis Techniques

Teacher perception data was collected by distributing questionnaires via Google Form. Teachers were given two weeks to complete the survey online. Prior to filling out the survey, teachers were presented with a statement asking for their voluntary participation. The teacher perception data regarding pedagogical approaches and student engagement in physics learning was analyzed by calculating the percentage of their responses to each statement item. The same analysis was also conducted on the questionnaire data regarding the professional development needs of teachers

Results and Discussion

The research results are categorized into two parts. The first part presents data on elementary school teachers' perceptions regarding pedagogical approaches and student engagement in learning, specifically in the subject of PHYSICS, covering topics such as force and motion, energy, and electricity.

The second part provides data on teachers' perceptions regarding the need for STEM literacy-based professional development.

Pedagogical Approach and Student Engagement in Teaching Physics Material in Elementary School

The survey on the analysis of teaching in elementary schools consists of the pedagogical approaches utilized by teachers in the classroom and student activities during the learning process. The percentage data regarding the pedagogical approaches employed by elementary school teachers in Bogor City can be observed in Table 1.

Table 1. The Pedagogical Approaches Employed by Elementary School Teachers

Pedagogical Approaches	N	Teacher's Response (%)			
		Never	Sometimes	Often	Always
Traditional Teaching	226	1	55	33	11
Teaching through Experiments	208	0	50	38	12
Problem/Project-Based Learning	200	1	44	40	15
Inquiry (Students design and conduct scientific investigations)	210	6	61	20	13
Collaborative Learning	210	1	24	52	22
Peer Teaching (Students are given the opportunity to teach their peers)	214	3	46	35	16
Flipped Classroom	220	8	55	24	12
Tailored Teaching and Learning to meet individual student interests, aspirations, and learning needs	199	4	40	42	14
Integrated Learning (Learning integrates content and skills from more than one subject).	201	3	39	42	16

Table 1 indicates that elementary school teachers rarely employ inquiry-based learning, experiments, problem-based learning, and flipped classroom methods in teaching physics content such as force and motion, energy, and electricity. However, science education, particularly in physics, demands learning through scientific and engineering practices as its primary focus. Additionally, collaborative learning emerges as one of the most frequently utilized approaches in classroom instruction. These findings suggest that elementary school teachers' pedagogical approaches to teaching physics content have not yet aligned with the essence of STEM education. This also provides evidence that the implementation of the Merdeka curriculum, which emphasizes STEM-based learning, has not progressed as intended. Therefore, strengthening the competence of teachers, particularly in STEM education, remains crucial.

In addition to analyzing the teaching approaches in elementary schools, the survey was also conducted to uncover the teachers' perspectives on the activities carried out by students during classroom learning. The survey results can be presented in Table 2.

Table 2. Teacher's Perspective on Student Activities during the Learning Process

Statements	Teacher's Response (%)			
	Never	Sometimes	Often	Always
Developing problem-solving skills through inquiry or scientific investigation	4	56	29	12
Working in groups	2	29	47	22
Making careful observations or measurements	2	54	30	14
Formulating testable predictions	12	52	24	13
Using equipment to gather data, such as computers, software, scales, etc.	13	48	26	12
Recording, writing, or drawing information in one's own format	8	42	35	14
Recognizing patterns in data	14	48	24	13
Creating explanations based on experimental or investigative outcomes	5	50	31	14
Reasoning quantitatively	7	51	29	12

Statements	Teacher's Response (%)			
	Never	Sometimes	Often	Always
Studying STEM or careers related to the content.	14	50	13	13

The data in Table 2 indicates that elementary school students are still rarely engaged in scientific and engineering practices during physics content learning in the classroom. Furthermore, the instruction of physics content is not integrated with STEM disciplines. This aligns with the findings in Table 1, which demonstrate the limited involvement of students in scientific and engineering practices due to teachers not employing suitable STEM education approaches when teaching physics material. These results can also be interpreted as emphasizing that strengthening teachers' competence, especially in STEM education, will influence student engagement in the classroom.

These findings are consistent with several research results indicating that teachers who employ STEM approaches in instruction are capable of enhancing student activities and engagement in problem-solving, inquiry, and engineering practices (Hall & Miro, 2016; Kennedy & Odell, 2014; Struyf et al., 2019; Sulaeman et al., 2021). When teachers utilize approaches that lead to activities resembling those of scientists or engineers in the classroom (such as identifying problems, designing models, conducting investigations, employing computational and mathematical thinking, designing solutions, and communicating), student engagement in these activities becomes more prominent. These activities require students to work like scientists and engineers to find solutions provided by the teacher in the classroom. Consequently, the learning process in the classroom becomes more active compared to traditional teaching methods. This is in line with Wagner et al.'s research, which reveals that scientific and engineering-based learning can enhance problem-solving skills and the scientific and engineering skills of learners (Wagner et al., 2017). Wagner et al. also assert that integrating engineering makes it easier for students to see the connections between science and mathematics in real-world problem-solving processes (Wagner et al., 2017). Therefore, based on these findings, there is a need for the introduction and development of competencies for elementary school teachers related to STEM education.

Teacher's Perception regarding STEM Literacy-Based Professionalism Development

The analysis of professional development needs was conducted to explore data on the types of support, teacher attitudes, and types of professional development based on the experience of elementary school teachers. The survey results regarding the types of support for professional development based on teachers' experiences can be seen in Table 3.

Table 3. Types of Support for Teacher Professional Development

Statements	Internal Support (%)	External Support (%)	Not available / Not applicable (%)
Formal Education	48	35	17
Courses/Training	49	43	7
National and International Exchanges	27	33	40
Attending academic events, such as seminars, workshops, or conferences	54	43	2
Peer Studies	49	41	10
Self-directed Learning	58	40	2
Having a Mentor	41	41	19
Support in conducting research	45	39	16
Support in teaching	54	43	3

Table 3 shows that only 43% of teachers receive professional development support in the form of training from external sources. Additionally, less than 50% of teachers have received external support in teaching and research. This survey result indicates that elementary school teachers feel that support from external sources is still very limited, particularly in the form of training, research, and teaching. Therefore, the role of external entities such as universities, education practitioners, and researchers is crucial to the professional development of elementary school teachers. When professional development practices involve external parties, it is highly effective for teachers to problem-solve and learn together, which can contribute positively to student achievement (Darling-Hammond et al., 2017).

Several studies also indicate that teachers who engage in collaboration with external parties in various activities (such as designing effective learning, discussing science concepts, and reflecting on student learning) during professional development are able to enhance the effectiveness of teaching in the classroom (Buczynski & Hansen, 2010; Doppelt et al., 2009; Lara-Alecio et al., 2012). Additionally, students who have direct experiences with these teachers achieve higher academic performance compared to students taught by teachers not involved in professional development practices (Buczynski & Hansen, 2010; Doppelt et al., 2009; Lara-Alecio et al., 2012). Further analysis was also conducted on the perspectives and attitudes of elementary school teachers regarding their professional practices, which can be seen in Table 4.

Table 4. Attitudes of Elementary School Teachers towards Professional Practices

Statements	Very Agree (%)	Agree (%)	Disagree (%)	Very Disagree (%)
I have the opportunity to collaborate with my colleagues.	34	65	1	0
I am competent in the subject matter I teach.	24	71	5	0
I am competent in the pedagogy of the subjects I teach.	21	72	7	0
I need training to teach students professionally.	36	62	2	0
I self-study what I need for my professional development and advancement.	23	70	7	0
I learn what I need for professional development and advancement by attending workshops outside my institution.	24	72	3	1
I learn what I need for professional development and advancement by attending workshops within my institution.	25	73	2	0
My colleagues help me learn what I need for professional development and advancement.	25	72	2	1

Table 4 indicates that the majority of elementary school teachers responded positively to their professional practices. They are aware that developing professional practices can enhance their competence in both pedagogy and the subjects they teach in class, and they also have the opportunity to collaborate with their peers. Furthermore, they recognize the need for continuous learning, whether through self-study or workshops. Collaborative efforts among teachers yield numerous benefits with significant impacts on their professional lives, thus playing a crucial role in the professional development of teachers (Vangrieken et al., 2015). For instance, the Teaching and Learning International Survey (TALIS, 2013) found that teachers who employ collaborative practices are more innovative in the classroom, experience higher job satisfaction, and possess stronger self-efficacy beliefs (Postholm, 2018).

In addition to data on teachers' attitudes towards their professional practices, an analysis was also conducted on their experiences with professional development practices they have participated in. The results of the analysis on the types and durations of professional development activities that elementary school teachers have engaged in are shown in Table 5. The findings in Table 5 indicate that the majority of elementary school teachers have never received training in STEM education. Some studies also indicate that the majority of STEM education training is provided for middle school teachers, with only three studies conducted for elementary school teachers, particularly in the United States (Nadelson et al., 2013; Parker et al., 2015; Radloff & Guzey, 2017). However, professional development in STEM for elementary school teachers can lead to a deeper understanding of STEM content, a stronger commitment to inquiry-based learning activities, and a tendency towards higher student achievement (Buczynski & Hansen, 2010).

Teachers typically attend training sessions that last less than 1 day or span between 1 and 3 days, as indicated by the survey results. Only a small portion of teachers have received training over a period of six days. However, sustained professional development programs tend to have a more significant impact. Yoon suggests that an effective professional development program averages about 49 hours of development per year (Yoon, 2007). Additionally, Penuel et al. developed a two-week training program, and the results showed that such training can promote meaningful learning. Sustained professional development offers opportunities for teachers to continue their learning beyond formal meetings, whether in their own classrooms, through collaboration with colleagues, or in less formal ways (Penuel et al., 2011).

Darling-Hammond et al. (2009) argue that the duration of professional development has a stronger impact on both teacher and student learning. Sustained professional development typically involves the application of practices, often supported by learning groups and/or coaching. This provides teachers with the opportunity to refine and apply their understanding of the material in their classrooms (Darling-Hammond et al., 2017). Johnson and Fargo (2014) engaged teachers in an intensive summer workshop for an entire academic year. The program began with a two-week summer workshop that included lectures on basic science teaching as well as an orientation to the new inquiry-based science curriculum and strategies for culturally relevant pedagogy. Furthermore, the program was reinforced with independent work and monthly grade-level workshops with a professional learning community. These additional sessions aimed to support teachers in deepening their learning and provided space for ongoing support in the implementation of the new curriculum. The results of this professional development showed that teachers gained more meaningful learning experiences. Additionally, students taught by these teachers demonstrated higher achievements compared to teachers who did not receive sustained training (Johnson & Fargo, 2014). These studies highlight the importance of continuous professional development for teachers. Sustained programs can provide more meaningful experiences for teachers, offer intensive collaboration opportunities between teachers and professionals, and allow teachers to apply their learning directly to their professional practice.

Table 5. Types of Professional Development and Duration Attended by Teachers

Statements	Never	< 1 day	1-3 days	4-6 days	> 6 days
Training on basic Internet usage and common applications (basic word processing, spreadsheet, presentation, database, etc.)	26	37	33	0	4
Advanced training on applications (advanced word processing, complex relational databases, Virtual Learning Environments, etc.)	35	37	25	1	3
Advanced training on Internet usage (creating websites/homepages, video conferencing, etc.)	33	40	23	1	3
Specialized equipment training (interactive whiteboards, laptops, etc.)	36	38	23	1	2
Training on using ICT in teaching and learning	26	42	27	1	4
Training on educational applications (tutorials, simulations, etc.)	24	45	27	1	3
Multimedia courses (using digital video, audio equipment, etc.)	39	37	20	1	2
Participation in communities (e.g., online: mailing lists, Twitter, blogs; or face-to-face: working groups, associations...) for professional discussions with other teachers	23	46	24	1	5
Self-learning about innovative STEM teaching	49	31	17	2	1
Collaboration with industry for contextualizing STEM teaching (joint development of learning resources, industry placements)	55	29	15	2	0
Other professional development opportunities related to innovative STEM teaching	53	28	18	0	0

Conclusion

The results of this study indicate that in the teaching of physics content in elementary schools, teachers rarely use inquiry-based, experimental, and problem-based learning approaches. Additionally, the teaching of physics content in elementary schools is not associated with STEM disciplines. As a result, student engagement in scientific and engineering practices is seldom observed in the teaching of physics content in the classroom. The low level of student engagement in these practices may be attributed to the limited knowledge of elementary school teachers regarding inquiry-based and engineering education. Findings reinforce this assumption, indicating that the majority of elementary school teachers have never participated in professional development programs related to STEM education. Despite this, the majority of teachers hold a positive attitude towards professional development programs, which have a positive impact on their competence.

Furthermore, this research also indicates a lack of external support (such as from universities, education practitioners, and researchers) for teachers in professional development programs. Moreover, the professional development programs are not carried out in a sustained manner. This phenomenon renders professional development programs less meaningful for enhancing teacher competence and the quality of classroom teaching.

Therefore, there is a need for sustained STEM-based professional development programs for elementary school teachers that involve various stakeholders, such as universities, education authorities, STEM practitioners, and school principals. The collaboration of various parties in professional development programs is expected to enhance the relevance of STEM learning in the classroom.

Acknowledgment

We express our gratitude to the Directorate General of Higher Education, Research, and Technology for providing research funding under the title "Development of an Elementary School Teacher Professionalism Model based on STEM Literacy with Pentahelix Strategy," with Master Contract Number: 180/E5/PG.02.00PL/2023 and Sub-Contract Number: 05/LPPM-UP/RT-MONO/VIII/2023. We would also like to thank Pakuan University for facilitating the research administration, the Indonesian University of Education as our research partner, and the Department of Education and Elementary School Teachers in Bogor City as the users and subjects of this study.

References

Ardianto, D., Rubini, B., & Pursitasari, I. D. (2021). *Analisis Literasi dan Minat STEM Siswa di Kota Bogor dan Kabupaten Cianjur.* [Laporan Penelitian]. Universitas Pakuan.

Bidang Pengelolaan Data Ketenagakerjaan. (2021). *Ketenagakerjaan Dalam Data* (4th ed.). Pusat Data dan Teknologi Informasi Ketenagakerjaan.

Brown, R. E., & Bogiages, C. A. (2019). Professional Development Through STEM Integration: How Early Career Math and Science Teachers Respond to Experiencing Integrated STEM Tasks. *International Journal of Science and Mathematics Education*, *17*(1), 111–128. https://doi.org/10.1007/s10763-017-9863-x

Buczynski, S., & Hansen, C. B. (2010). Impact of professional development on teacher practice: Uncovering connections. *Teaching and Teacher Education*, *26*(3), 599–607. https://doi.org/10.1016/j.tate.2009.09.006

Cavlazoglu, B., & Stuessy, C. (2017). Changes in science teachers' conceptions and connections of STEM concepts and earthquake engineering. *The Journal of Educational Research*, *110*, 239–254. https://doi.org/10.1080/00220671.2016.1273176

Chai, C. S. (2019). Teacher Professional Development for Science, Technology, Engineering and Mathematics (STEM) Education: A Review from the Perspectives of Technological Pedagogical Content (TPACK). *The Asia-Pacific Education Researcher*, *28*(1), 5–13. https://doi.org/10.1007/s40299-018-0400-7

Darling-Hammond, L., Hyler, M., & Gardner, M. (2017). *Effective Teacher Professional Development*. Learning Policy Institute. https://doi.org/10.54300/122.311

Direktorat Statistik Kependudukan dan Ketenagakerjaan. (2022). *Booklet Survey Angkatan Kerja Nasional Agustus 2022*. Badan Pusat Statistik Republik Indonesia.

Doppelt, Y., Schunn, C. D., Silk, E. M., Mehalik, M. M., Reynolds, B., & Ward, E. (2009). Evaluating the impact of a facilitated learning community approach to professional development on teacher practice and student achievement. *Research in Science & Technological Education*, *27*(3), 339–354. https://doi.org/10.1080/02635140903166026

Faber, C., Hardin, E., Klein-Gardner, S., & Benson, L. (2014). Development of Teachers as Scientists in Research Experiences for Teachers Programs. *Journal of Science Teacher Education*, *25*, 785–806. https://doi.org/10.1007/s10972-014-9400-5

Firman, H. (2015). Pendidikan STEM. *Prosiding Seminar Nasional Pendidikan IPA Dan PKLH*, 1–9.

Fore, G. A., Feldhaus, C. R., Sorge, B. H., Agarwal, M., & Varahramyan, K. (2015). Learning at the nano-level: Accounting for complexity in the internalization of secondary STEM teacher professional development. *Teaching and Teacher Education: An International Journal of Research and Studies*, *51*(1), 101–112.

Guzey, S. S., Harwell, M., & Moore, T. (2014). Development of an Instrument to Assess Attitudes Toward Science, Technology, Engineering, and Mathematics (STEM). *School Science and Mathematics*, *114*(6), 271–279. https://doi.org/10.1111/ssm.12077

Hall, A., & Miro, D. (2016). A Study of Student Engagement in Project-Based Learning Across Multiple Approaches to STEM Education Programs. *School Science and Mathematics*, *116*(6), 310–319. https://doi.org/10.1111/ssm.12182

Ismail, M. H. (2022). A Needs Analysis Study for the Preparation of Integrated STEM Instructional Practices through Scientist-Teacher-Student Partnership (STSP). *ASM Science Journal*, *null*, null. https://doi.org/10.32802/asmscj.2022.1112

Johnson, C. C., & Fargo, J. D. (2014). A Study of the Impact of Transformative Professional Development on Hispanic Student Performance on State Mandated Assessments of Science in Elementary School. *Journal of Science Teacher Education*, *25*(7), 845–859. https://doi.org/10.1007/s10972-014-9396-x

Kennedy, T. J., & Odell, M. R. L. (2014). *Engaging Students In STEM Education*.

Lara-Alecio, R., Tong, F., Irby, B. J., Guerrero, C., Huerta, M., & Fan, Y. (2012). The effect of an instructional intervention on middle school english learners' science and english reading achievement. *Journal of Research in Science Teaching*, *49*(8), 987–1011. https://doi.org/10.1002/tea.21031

Luo, W., Wei, H.-R., Ritzhaupt, A. D., Huggins-Manley, A. C., & Gardner-McCune, C. (2019). Using the S-STEM Survey to Evaluate a Middle School Robotics Learning Environment: Validity Evidence in a Different Context. *Journal of Science Education and Technology*, *28*(4), 429–443. https://doi.org/10.1007/s10956-019-09773-z

Nadelson, L. S., Callahan, J., Pyke, P., Hay, A., Dance, M., & Pfiester, J. (2013). Teacher STEM Perception and Preparation: Inquiry-Based STEM Professional Development for Elementary Teachers. *The Journal of Educational Research*, *106*(2), 157–168. https://doi.org/10.1080/00220671.2012.667014

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (p. 13165). National Academies Press. https://doi.org/10.17226/13165

OECD. (2014). *PISA 2012 Results in Focus* (p. 44). Organization for Economic Cooperation and Development (OECD).

OECD. (2018). *PISA 2015: Results in Focus* (p. 32). Organization for Economic Cooperation and Development (OECD).

OECD. (2019). *PISA 2018 Results*. Organization for Economic Cooperation and Development (OECD).

Parker, C. E., Stylinski, C. D., Bonney, C. R., Schillaci, R., & McAuliffe, C. (2015). Examining the Quality of Technology Implementation in STEM Classrooms: Demonstration of an Evaluative Framework. *Journal of Research on Technology in Education*, *47*(2), 105–121. https://doi.org/10.1080/15391523.2015.999640

Penuel, W. R., Gallagher, L. P., & Moorthy, S. (2011). Preparing Teachers to Design Sequences of Instruction in Earth Systems Science: A Comparison of Three Professional Development Programs. *American Educational Research Journal*, *48*(4), 996–1025. https://doi.org/10.3102/0002831211410864

Postholm, M. B. (2018). Teachers' professional development in school: A review study. *Cogent Education*, *5*(1), 1522781. https://doi.org/10.1080/2331186X.2018.1522781

Radloff, J., & Guzey, S. (2017). Investigating Changes in Preservice Teachers' Conceptions of STEM Education Following Video Analysis and Reflection: STEM Conceptions Following Video Reflection. *School Science and Mathematics*, *117*(3–4), 158–167. https://doi.org/10.1111/ssm.12218

Richmond, G., Dershimer, R. C., Ferreira, M., Maylone, N., Kubitskey, B., & Meriweather, A. (2017). Developing and sustaining an educative mentoring model of STEM teacher professional development through collaborative partnership. *Mentoring & Tutoring: Partnership in Learning*, *25*(1), 5–26. https://doi.org/10.1080/13611267.2017.1308097

Rubini, B., Pursitasari, I. D., Ardianto, D., & Hidayat, A. (2018). Science Teachers' Understanding on Science Literacy and Integrated Science Learning: Lesson from Teachers Training. *Jurnal Pendidikan IPA Indonesia*, *7*(3). https://doi.org/10.15294/jpii.v7i3.11443

Sadler, P., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and Volatility of STEM Career Interest in High School: A Gender Study. *Science Education*, *96*, 411–427. https://doi.org/10.1002/sce.21007

Salami, M. A. A., Makela, C., & Miranda, M. A. (2017). Assessing changes in teachers' attitudes toward interdisciplinary STEM teaching. *International Journal of Technology and Design Education*, *27*, 63–88. https://doi.org/10.1007/S10798-015-9341-0

Sjaastad, J. (2013). Measuring the Ways Significant Persons Influence Attitudes Towards Science and Mathematics. *International Journal of Science Education*, *35*(2), 192–212. https://doi.org/10.1080/09500693.2012.672775

Struyf, A., De Loof, H., Boeve-de Pauw, J., & Van Petegem, P. (2019). Students' engagement in different STEM learning environments: Integrated STEM education as promising practice? *International Journal of Science Education*, *41*(10), 1387–1407. https://doi.org/10.1080/09500693.2019.1607983

Sulaeman, N. F., Putra, P. D. A., Mineta, I., Hakamada, H., Takahashi, M., Ide, Y., & Kumano, Y. (2021). Exploring Student Engagement in STEM Education through the Engineering Design Process. *Jurnal Penelitian Dan Pembelajaran IPA*, *7*(1), 1. https://doi.org/10.30870/jppi.v7i1.10455

Tyler-Wood, T., Knezek, G., & Christensen, R. (2010). *Instruments for Assessing Interest in STEM Content and Careers*. *18*(2), 341–363.

Vangrieken, K., Dochy, F., Raes, E., & Kyndt, E. (2015). Teacher collaboration: A systematic review. *Educational Research Review*, *15*, 17–40. https://doi.org/10.1016/j.edurev.2015.04.002

Wagner, T. P., McCormick, K., & Martinez, D. M. (2017). Fostering STEM literacy through a tabletop wind turbine environmental science laboratory activity. *Journal of Environmental Studies and Sciences*, *7*(2), 230–238. https://doi.org/10.1007/s13412-015-0337-6

Yoon, K. S. (2007). *Reviewing the evidence on how teacher professional development affects student achievement*. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Southwest.