REVIJA ZA ELEMENTARNO IZOBRAŽEVANJE
JOURNAL OF ELEMENTARY EDUCATION
Vol. 18, No. 4, pp. 361–376, December 2025

INVESTIGATING ELEMENTARY SCHOOL TEACHERS' KNOWLEDGE TRANSFORMATION IN PROJECT-BASED EXPERIENTIAL STEAM LEARNING

YUDI YUNIKA PUTRA[1], VIKA MARTAHAYU[1], IMAM FITRI RAHMADI[2], JOKO SUTRISNO AB[3] & HOUSSAM KASTI[4]

[1]Faculty of Teacher Training and Education, Universitas Muhammadiyah Bangka Belitung, Indonesia
[2]Faculty of Education, Universitas Negeri Jakarta, Indonesia
[3]Mathematics Education Department, STKIP PGRI Bandar Lampung, Indonesia
[4]General Education Department, Qatar University, Qatar

CORRESPONDING AUTHOR/KORESPONDENČNI AVTOR/
yudi.yunikaputra@unmuhbabel.ac.id

Potrjeno/Accepted
19. 10. 2025

Objavljeno/Published
15. 12. 2025

Abstract/Izvleček

Successfully implementing project-based experiential science, technology, engineering, arts, and mathematics (STEAM) learning hinges on the teachers' comprehension of fundamental concepts. This study investigates elementary school teachers' knowledge transformation of project-based experiential STEAM learning after participating in a focused STEAM education workshop. Through an investigative exploration with the participation of five elementary school teachers, this study reveals that participating teachers better comprehend STEAM as an educational approach after the workshop. Meanwhile, their understanding of project-based learning decreased, and experiential learning remained unchanged. This study suggests an integrated form of training that equally addresses the interconnected components of STEAM, project-based, and experiential learning.

Preučevanje preoblikovanja znanja osnovnošolskih učiteljev pri projektno zasnovanem izkustvenem učenju znanosti, tehnologije, inženirstva, umetnosti in matematike (angl. STEAM) Uspešno izvajanje projektnega izkustvenega učenja znanosti, tehnologije, inženirstva, umetnosti in matematike (angl. STEAM) je odvisno od učiteljevega razumevanja temeljnih konceptov. V študiji raziskujemo transformacijo znanja osnovnošolskih učiteljev o projektnem izkustvenem učenju STEAM po udeležbi na izobraževalni delavnici, osredinjeni na STEAM. S preiskovalno raziskavo, v kateri je sodelovalo pet osnovnošolskih učiteljev, ugotavljamo, da sodelujoči učitelji po delavnici bolje razumejo STEAM kot izobraževalni pristop. Medtem se je njihovo razumevanje projektnega učenja zmanjšalo, izkustveno učenje pa je ostalo nespremenjeno. Na osnovi ugotovitev predlagamo integrirano usposabljanje, ki enako obravnava medsebojno povezane komponente STEAM, projektnega in izkustvenega učenja.

Keywords:
teacher knowledge, project-based learning, experiential learning, STEAM learning, hands-on activities.

Ključne besede:
znanje učiteljev, projektno učenje, izkustveno učenje, učenje STEAM, praktične dejavnosti.

UDK/UDC
37.011.3-051:374.7

DOI https://doi.org/10.18690/rei.4967

Introduction

Science, technology, engineering, arts, and mathematics (STEAM) education has gained prominence as an approach to interdisciplinary learning. It fosters critical thinking, creativity, and problem-solving skills (De Vries, 2021; Liao, 2016). Among the most effective methods of engaging students in STEAM learning, project-based experiential learning (Kolb, 2015; Krajcik and Blumenfeld, 2006) encourages students to explore and apply concepts through hands-on activities. This approach enhances their understanding of theoretical principles and promotes collaboration, adaptability, and innovation as students work on real-world challenges. STEAM education supports a holistic learning environment by integrating the arts into STEM disciplines; at the same time, it nurtures diverse perspectives and bridges the gap between technical knowledge and creative expression. Such approaches prepare students to thrive in a rapidly evolving world where interdisciplinary skills are increasingly essential for success in various fields.

The successful implementation of project-based experiential STEAM learning hinges on the teachers' comprehension of the relevant fundamental concepts. Teachers are pivotal in guiding students through experiential learning processes (Avalos, 2011). Nevertheless, many educators face challenges in adopting this learning approach because of a lack of understanding and resources. Without a solid foundation in the interdisciplinary nature of STEAM, teachers may struggle to design and facilitate activities that effectively integrate the various disciplines. Additionally, limited access to professional development opportunities and insufficient instructional materials can hinder their ability to fully embrace STEAM pedagogy's potential.

Several studies have suggested strengthening teachers' understanding of new pedagogical approaches to ensure robust practice. For instance, Darling-Hammond, Hyler, and Gardner (2017) emphasize that targeted workshops or professional development can enhance teachers' capacity to implement innovative instructional methods effectively. Similarly, Desimone and Garet (2015) highlight the importance of sustained, collaborative training that focuses on practical application and reflection to deepen pedagogical understanding. (Guskey, 2002) argues that teachers must be prepared for any instructional practice changes to meet teachers' needs and student learning goals. The greater the comprehension of specific pedagogies, the better the classroom practice.

The present study investigates elementary school teachers' knowledge transformation of project-based experiential STEAM learning after participating in a focused STEAM education workshop. Two research questions were posed:

1. How did elementary school teachers change their knowledge of project-based experiential STEAM learning after participating in a focused STEAM education workshop?
2. How did elementary school teachers understand STEAM learning after participating in a focused STEAM education workshop?

Through an investigative exploration, the present study contributes to the growing literature on teachers' comprehension of an interdisciplinary learning approach that integrates science, technology, engineering, arts, and mathematics through experiential projects. A key novelty of this study lies in its focus on the conception of STEAM learning implemented through project-based and experiential learning. Following the introduction, this article addresses the underlying theoretical framework, reports the methodology used, presents results and critical discussion, and offers a reflective conclusion.

Conceptual Background

Project-based experiential STEAM learning integrates the principles of project-based learning (PBL) and experiential learning within the interdisciplinary context of STEAM education. This approach emphasizes hands-on, real-world tasks that engage students in applying science, technology, engineering, arts, and mathematics through meaningful, inquiry-driven projects (Diego-Mantecón et al., 2021; Ge et al., 2015). By fostering creativity, critical thinking, collaboration, and problem-solving, it offers a dynamic, student-centred learning environment that enhances engagement and deepens conceptual understanding. Figure 1 illustrates the project-based experiential STEAM learning stages, which combine the cycle of project-based (Kokotsaki et al., 2016) and experiential learning (Kolb, 2015).

Figure 1 illustrates cyclical and interconnected project-based experiential STEAM learning phases that cover orientation, active experimentation, concrete experience, reflective observation, abstract conceptualization, and presentation. The orientation of learning aims, materials, processes, and examination initiates project-based experiential STEAM learning. Subsequently, it turns to the experiential learning cycle by planning, doing, reviewing, and concluding projects.

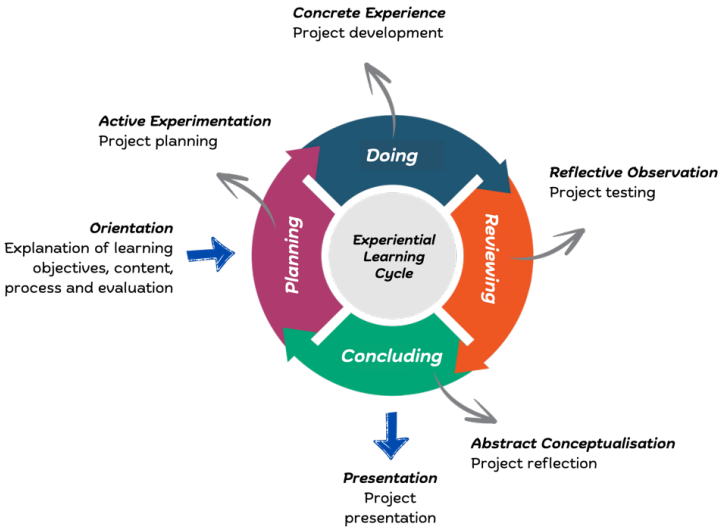

Figure 1
Project-based Experiential STEAM Learning Stages

Active experimentation reflects the planning and application of new ideas in the following experience or situation. Concrete experience refers to engagement in a hands-on activity. Reflective observation initiates reflection on and review of the experience. Abstract conceptualization forms conclusions and theories based on reflection. Finally, it is finished by presenting the developed projects and sharing experiences. The project-based experiential STEAM learning phases indicate how experience is transformed into knowledge through reflection, conceptualization, and experimentation in interdisciplinary hands-on activities.

To enhance conceptual clarity, it is important to differentiate between project-based learning (PBL), experiential learning, and STEAM education, as each represents a distinct yet potentially overlapping pedagogical framework. Project-based learning emphasizes student-driven inquiry through extended, real-world tasks that culminate in a tangible product or presentation (Kokotsaki, Menzies, and Wiggins, 2016). Experiential learning, rooted in Dewey and Kolb's theories (Kolb, 2015), focuses more broadly on learning through direct experience, reflection, and active engagement, regardless of whether the learning is organized around a specific project. STEAM education, on the other hand, integrates science, technology, engineering, the arts, and mathematics, aiming to foster interdisciplinary or even transdisciplinary learning experiences that encourage creativity and innovation (Liao,

2016). While STEAM approaches often utilize PBL and experiential methods, the frameworks should not be conflated, as each brings unique theoretical foundations and instructional goals.

Methods

An investigative exploration through a focused workshop was conducted to introduce the notion of project-based experiential STEAM learning. Consequently, the exploration measures elementary school teachers' changing knowledge of project-based experiential STEAM learning and understanding of STEAM learning in common. Stebbins (2001) describes investigative exploration as an inquisitive process of examining and investigating social science matters, which aligns with the qualitative approach adopted in this study. The primary concern was teachers' comprehension of an interdisciplinary learning approach, since misconceptions can hinder effective classroom practice. Introducing teachers to the conception of project-based experiential STEAM learning and assessing their understanding was thus essential. In line with Moser and Korstjens (2018), purposive sampling, structured data collection, and thematic analysis were employed to ensure rigour in capturing and interpreting the teachers' professional learning experiences.

Participants

This study involved elementary school teachers from a private school in Pangkalpinang, Kepulauan Bangka Belitung, Indonesia. The school was purposefully selected because it had just initiated STEAM programs at the beginning of 2024. Background information for the participating teachers is provided in Table 1.

Table 1
Participating Teachers' Profiles

Teachers	Gender	Age	Education	Teaching Experience	STEAM Familiarity
T1	Male	<25	Bachelor	<5 years	Not very familiar
T2	Male	36-45	Bachelor	5-10 years	Not at all familiar
T3	Male	25-35	Bachelor	<5 years	Not at all familiar
T4	Male	25-35	Bachelor	<5 years	Not very familiar
T5	Female	25-35	Bachelor	<5 years	Not very familiar

Table 1 describes the profile of elementary school teachers who participated in this study. Most teachers were male, and only one female teacher was involved. The school principal selected them based on their interest in STEAM education. They each have a bachelor's degree, teaching experience of at most 10 years, and limited familiarity with STEAM education.

Purposive sampling was employed in this study to intentionally select participants who met specific criteria relevant to the research focus. As shown in Table 1, the participating elementary school teachers were selected by the school principal based on their expressed interest in STEAM education and their willingness to engage in professional development. All participants held a bachelor's degree, had no more than ten years of teaching experience, and reported limited prior exposure to STEAM education. These characteristics made them well-suited to explore how early-career teachers with minimal STEAM background begin to conceptualize and engage with project-based experiential STEAM learning. This targeted sampling approach aligns with the study's exploratory aims, as it enables in-depth insight into the learning processes of a specific, relevant teacher group rather than aiming for broad generalizability. Figure 2 also describes their personal and professional backgrounds and characteristics in responding to innovation.

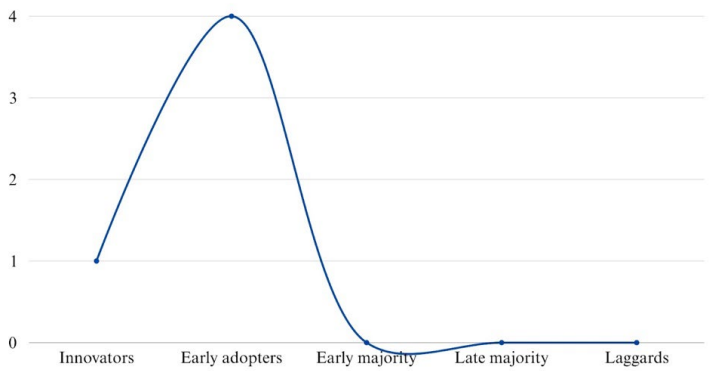

Figure 2
Teachers' Characteristics in Responding to Innovation

Figure 2 describes the characteristics of participating teachers in responding to innovation. It was categorized based on diffusion on innovation theory (Rogers, 2003). It is clear from the figure that four out of five teachers are early adopters, meaning they are quick to embrace and implement new instructional strategies, tools,

or technologies. One teacher is identified as an innovator, indicating they are even more proactive in seeking and experimenting with novel ideas, often taking risks to pioneer new approaches before others in their schools. Knowing their attitude in accepting innovation allows researchers to tailor strategies for further introducing STEAM education pedagogies.

Procedures

Research procedures outline the systematic steps or methods used to conduct a study. Investigation procedures guide researchers in collecting, analysing, and interpreting data (Moser and Korstjens, 2018). The detailed process of this study is illustrated in Figure 3.

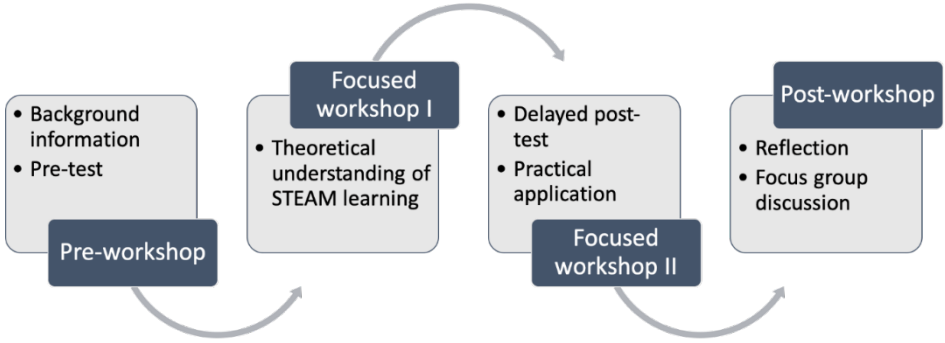

Figure 3
Investigative Exploration Stages

Figure 3 describes the procedures of current investigative exploration. It started with a pre-workshop activity that gathered background information and conducted preliminary tests for teachers. Afterward, the first focused workshop was implemented to introduce teachers to the theoretical considerations of STEAM learning. This was followed by the second focused workshop, which provided delayed post-tests and worked on developing STEAM activities, namely kirigami, tessellation, and educational robotics. The stage was concluded by a post-workshop consisting of reflection and focus group discussion.

Data Collection and Analysis

This study administered preliminary and delayed post-tests to generate data. The pre-test consists of multiple-choice questions to assess their initial knowledge of project-based experiential STEAM learning before the first workshop. The delayed post-test contains the same questions as the pre-tests, but the order was shuffled and there was an open question. After the first workshop, a delayed post-test was applied to examine the teachers' knowledge of project-based experiential STEAM learning. Meanwhile, the open question was asked to measure teachers' general understanding of STEAM learning. The generated data was analysed descriptively (Holcomb, 2016). Descriptive data analyses promote a clear understanding of a dataset's patterns, trends, and key characteristics. Unlike inferential analysis, which seeks to draw conclusions or make predictions about a population, descriptive analysis focuses on understanding the generated data.

To enhance analytical rigour and strengthen the validity of findings, this study employed method triangulation by combining quantitative data from pre- and post-workshop knowledge tests with qualitative data derived from participants' open-ended reflections. This mixed-method approach enabled a more comprehensive understanding of changes in teachers' knowledge and perspectives related to project-based experiential STEAM learning.

Ethics

The present study adheres to the Helsinki Declaration (Carlson et al., 2004) for human participation research. The teachers voluntarily participated, and issues about research ethics were communicated. They were informed that their involvement was confidential. Researchers agreed with the teachers that their participation would not influence any appraisal related to teaching performance. The workshop activities and all data generated from the study were used exclusively for scientific purposes.

Results

An investigative exploration was administered to introduce the idea of project-based experiential STEAM learning. Respecting the posed research question, this section presents findings related to teachers' changing knowledge of project-based experiential STEAM learning and understanding of STEAM learning in general.

Teachers' Changing Knowledge

Teachers' knowledge of project-based experiential STEAM learning evolves as they deepen their understanding of interdisciplinary teaching and adapt to emerging tools, pedagogical strategies, and student needs. Figure 4 presents teachers' knowledge transformation as a result of the focused workshop.

Figure 4 reveals the changes in teachers' knowledge about project-based experiential STEAM learning. Their understanding of STEAM learning delivered experimentally by the project increases in the delayed post-test in most respects.

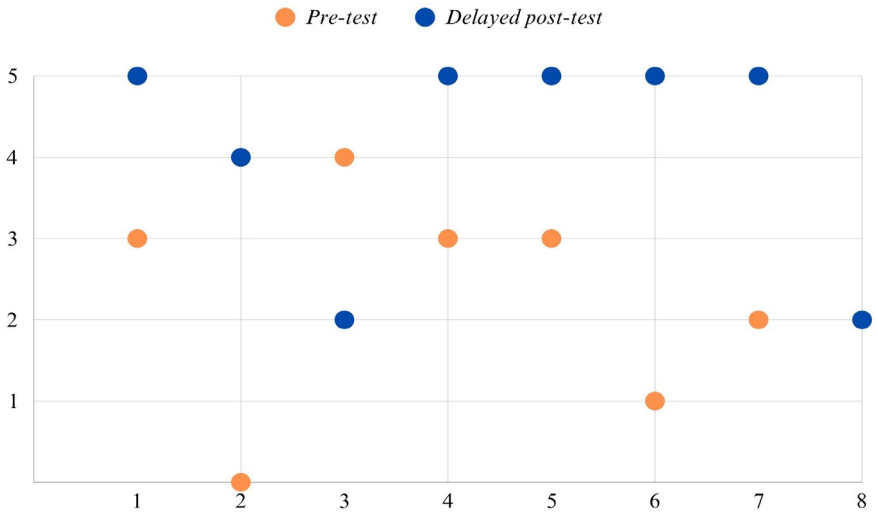

Figure 4

Transformation of Teachers' Knowledge of Project-based Experiential STEAM Learning

Aspects:

1. The abbreviation of STEAM
2. The basic concept of STEAM
3. The role of project-based learning in STEAM
4. The reason for arts inclusion in the STEM approach
5. The basic concept of kirigami
6. The basic concept of tessellation
7. The basic concept of educational robotics
8. The focus of experiential learning

Meanwhile, A decline in teachers' knowledge and constant comprehension can also be found. Before the workshop, none of the participating teachers understood the basic concept of STEAM as a learning approach. Only one gave a correct answer regarding the fundamental concept of tessellation. Following the workshop, all teachers have correct answers about the fundamental concept of STEAM and tessellation, the abbreviation STEAM, the reason for arts inclusion in the STEM approach, the basic concept of kirigami, and educational robotics. Nevertheless, project-based learning falls from four to two teachers with correct answers. The number of teachers that correctly answered the experiential learning aspect remained the same before and after the workshop.

Teachers' Understanding

Teachers' understanding of STEAM learning is crucial in effectively implementing this interdisciplinary approach. They need to understand that STEAM involves teaching these subjects in isolation and integrating them to solve real-world problems. Table 2 provides a summary of teachers' understanding of STEAM learning.

Table 2

Teachers' Understanding of STEAM Learning

Teachers	Statements	Remarks
T1	As the name implies, science, technology, engineering, arts, and mathematics (STEAM) learning is based on science, technology, engineering, arts, and mathematics.	Limited description, similar to its abbreviation
T2	A learning approach that studies science, technology, engineering, and mathematics is combined and processed with arts to make learning easier and more enjoyable.	Emphasis on integration, arts component, and enjoyable learning
T3	A learning strategy that helps teachers explain material in a fun way and does not quickly make students bored with learning.	Emphasis on enjoyable learning
T4	STEAM stands for science, technology, engineering, arts, and mathematics. It is also an approach that can be used for learning.	Recognition of the learning approach
T5	An interdisciplinary learning approach that contains science, technology, engineering, art, and mathematics.	Emphasis on interdisciplinary learning approaches

Table 2 describes the basic understanding of STEAM learning by participating teachers. From their perspectives, STEAM learning is an approach that promotes enjoyable learning. One teacher provides limited elaboration on STEAM learning. Teachers also mentioned concerns regarding integration and interdisciplinary approaches.

Discussion

This study investigated elementary school teachers' knowledge transformation of project-based experiential STEAM learning and comprehension of STEAM learning after participating in a focused STEAM education workshop. Five teachers participated in the investigative exploration, which revealed several key findings.

Prior to the workshop, none of the participating teachers demonstrated an understanding of the fundamental concept of STEAM as an educational approach. This finding indicates a critical need for essential knowledge regarding STEAM education by participating elementary school teachers. It is in line with the studies of Shernoff et al. (2017) and Yakman and Lee (2012), which reveal that although STEAM education is relatively popular worldwide, teachers tend to recognize it as a teaching method and strategy. After the focused workshop, teachers better understand STEAM as an approach to learning instead of methods or strategies. It is crucial to promote a shared perspective towards the basic concept of STEAM education (Belbase et al., 2022). Assuring their understanding is inevitable because teachers may need an appropriate understanding of STEAM education as a learning approach to design and facilitate interdisciplinary learning experiences that integrate science, technology, engineering, arts, and mathematics.

The number of teachers demonstrating a correct understanding of the role of project-based learning in STEAM education decreased from four to two following the workshop. This unexpected decline warrants careful interpretation. Rather than indicating a failure of the workshop, this shift may reflect a process of conceptual reorganization, as participants confronted and reconsidered prior assumptions in light of more nuanced understandings of PBL within a STEAM context. Barron et al. (2014) note that effective PBL requires deep pedagogical shifts, including the integration of inquiry, collaboration, and sustained problem solving—elements that may initially challenge teachers' established practices. Similarly, Herro, Quigley, and Cian (2019) highlight that implementing STEAM-based PBL can expose tensions in instructional planning and content integration, especially when teachers are new to

interdisciplinary approaches. The decline in self-reported understanding may indicate a productive phase of cognitive dissonance as teachers moved from surface-level familiarity toward a more critical and reflective engagement with the complexities of project-based experiential STEAM learning.

The number of teachers providing correct answers regarding experiential learning remained unchanged before and after the workshop. This stability suggests that while the workshop may have reinforced existing knowledge among some participants, it did not lead to significant knowledge transformation in this respect. One possible explanation is that experiential learning (Kolb, 2015; Morris, 2020) may have been unfamiliar to these teachers. On the other hand, the workshop content might not have adequately emphasized or clarified this component in the context of STEAM learning. To avoid misconceptions and inappropriate practices, it is pivotal to further introduce pedagogical innovation (Rahmadi and Lavicza, 2021) in terms of experiential learning application in STEAM educational activities.

Regarding their understanding of STEAM learning, the teachers recognized STEAM as an enjoyable educational approach, and this constitutes one positive outcome of the workshop. This shift in perception is significant, as teachers' attitudes toward a pedagogical method can significantly influence their willingness and enthusiasm to implement it in their classrooms (Herro et al., 2019). Viewing STEAM as enjoyable reflects its potential to create a dynamic and interactive learning environment. It suggests that the workshop succeeded in conveying the creative and exploratory nature of STEAM education. Another key outcome of the workshop was teachers' acknowledgment of the integration and interdisciplinary aspects of STEAM learning. This recognition is crucial, reflecting a deeper understanding of how STEAM transcends traditional subject boundaries to create a cohesive learning experience (Lavicza et al., 2018; Liao, 2016). By identifying integration as a core element, teachers demonstrate an awareness of how STEAM connects science, technology, engineering, arts, and mathematics to solve real-world problems collaboratively and creatively.

To strengthen the theoretical foundation of this study, we further elaborate on STEAM as an integrated and transdisciplinary educational approach. STEAM education moves beyond the mere inclusion of discrete disciplines, instead promoting the synthesis of science, technology, engineering, the arts, and mathematics to foster holistic and innovative thinking. As Yakman and Lee (2012) suggest, effective STEAM education is grounded in a transdisciplinary framework where subject boundaries are intentionally blurred, enabling learners to engage in

authentic, real-world problem solving. Similarly, Perignat and Katz-Buonincontro (2019) emphasise that successful STEAM integration involves not only curriculum design but also pedagogical strategies that support creative inquiry, critical thinking, and collaboration. This theoretical grounding informs the design and analysis of the present study, as it aims to capture how teachers conceptualise and begin to apply integrated approaches to teaching and learning within the context of a project-based experiential STEAM workshop.

In conclusion, this study highlights teachers' growing understanding of project-based experiential STEAM learning within the context of a focused STEAM education workshop. This evolving understanding can be interpreted through the lens of Pedagogical Content Knowledge (PCK), as participants demonstrated increasing ability to integrate content and pedagogy in meaningful ways (van Driel, Verloop and de Vos, 1998). Furthermore, the workshop design aligned with key principles of effective professional development outlined by Desimone and Garet (2015), supporting adult learning through active engagement, content focus, and collaborative reflection.

The present study is limited in some respects. It focuses on probing teachers' knowledge transformation in relation to project-based experiential STEAM learning and STEAM education generally as a result of a focused workshop. This investigative exploration involved mainly teachers from one school. Future studies could consider investigating their changing knowledge from longitudinal professional development workshops or programs and inviting teachers from other schools.

Conclusions

The present study has revealed the alteration of elementary school teachers' comprehension of project-based experiential STEAM learning. The main aim of this study was to investigate their knowledge development after receiving a focused workshop on the STEAM educational approach supported by project-based and experiential learning. Results of this study reveal that, after the workshop, teachers better understood STEAM as an approach to learning. Meanwhile, their comprehension of project-based learning decreased, and experiential learning remained unchanged. An implication of this is to provide integrated training that equally addresses the interconnected components of STEAM, project-based, and

experiential learning to achieve a holistic and lasting improvement in teachers' pedagogical knowledge of project-based experiential STEAM learning. The current study has focused on investigating the growing knowledge of elementary school teachers from a single school and a one-time workshop. Further work must be done to facilitate longer workshops involving teachers from multiple schools.

Acknowledgment

The authors want to acknowledge the elementary school teachers who voluntarily participated in the present study and the Directorate General of Research and Development Strengthening (DRPM), Ministry of Research, Technology and Higher Education (Kemenristekdikti) of Indonesia, which funded this research. Reference numbers: 0459/E5/PG.02.00/2024 and 104/E5/ PG.02.00.PL/2024.

References

Avalos, B. (2011). Teacher professional development in Teaching and Teacher Education over ten years. *Teaching and Teacher Education*, *27*(1), 10–20. https://doi.org/10.1016/j.tate.2010.08.007

Barron, B. J. S., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., and Bransford, J. D. (1998). Doing With Understanding: Lessons From Research on Problem- and Project-Based Learning. In C, E, Hmelo and S. M. Williams (eds), *Learning Through Problem Solving*. Psychology Press.

Belbase, S., Mainali, B. R., Kasemsukpipat, W., Tairab, H., Gochoo, M., and Jarrah, A. (2022). At the dawn of Science, technology, engineering, arts, and mathematics (STEAM) education: Prospects, priorities, processes, and problems. *International Journal of Mathematical Education in Science and Technology*, *53*(11), 2919–2955. https://doi.org/10.1080/0020739X.2021.1922943

Carlson, R. V., Boyd, K. M., and Webb, D. J. (2004). The revision of the Declaration of Helsinki: Past, present, and future. *British Journal of Clinical Pharmacology*, *57*(6), 695–713. https://doi.org–/10.1111/j.1365-2125.2004.02103.x

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

De Vries, H. (2021). Space for STEAM: New Creativity Challenge in Education. *Frontiers in Psychology*, *12*, 586318. https://doi.org/10.3389/fpsyg.2021.586318

Desimone, L. M., and Garet, M. S. (2015). Best Practices in Teachers' Professional Development in the United States. *Psychology, Society, & Education*, *7*(3), 252. https://doi.org/10.25115/psye.v–7i3.515

Diego-Mantecón, J.-M., Blanco, T.-F., Ortiz-Laso, Z., and Lavicza, Z. (2021). STEAM projects with KIKS format for developing key competencies. *Comunicar*, *29*(66), 33–43. https://doi.or–g/10.3916/C66-2021-03

Diego-Mantecon, J.-M., Prodromou, T., Lavicza, Z., Blanco, T. F., and Ortiz-Laso, Z. (2021). An attempt to evaluate STEAM project-based instruction from a school mathematics perspective. *ZDM – Mathematics Education*, *53*(5), 1137–1148. https://doi.org/10.1007/s11–858-021-01303-9

Ge, X., Ifenthaler, D., and Spector, J. M. (2015). Moving Forward with STEAM Education Research. In X. Ge, D. Ifenthaler, and J. M. Spector (eds.), *Emerging Technologies for STEAM Education* (pp. 383–395). Springer International Publishing. https://doi.org/10.1007/978-3-31902573-5_20

Guskey, T. R. (2002). Professional Development and Teacher Change. *Teachers and Teaching*, *8*(3), 381–391. https://doi.org/10.1080/135406002100000512

Herro, D., Quigley, C., and Cian, H. (2019). The Challenges of STEAM Instruction: Lessons from the Field. *Action in Teacher Education*, *41*(2), 172–190. https://doi.org/10.1080/01626620.201–8.1551159

Holcomb, Z. C. (2016). *Fundamentals of Descriptive Statistics*. Routledge.

Kokotsaki, D., Menzies, V., and Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, *19*(3), 267–277. https://doi.org/10.1177/1365480216659733

Kolb, D. A. (2015). *Experiential Learning: Experience as the Source of Learning and Development* (Second edition). Pearson Education, Inc.

Krajcik, J. S., and Blumenfeld, P. C. (2006). Project-based learning. In R. K. Sawyer (ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 317–333). Cambridge University Press.

Lavicza, Z., Fenyvesi, K., Lieban, D., Park, H., Frame, D., Hohenwarter, M., Mantecon, J. D., and Prodromou, T. (2018). *Mathematics Learning Through Arts, Technology and Robotics: Multi-And Transdisciplinary Steam Approaches*.14.

Liao, C. (2016). From Interdisciplinary to Transdisciplinary: An Arts-Integrated Approach to STEAM Education. *Art Education*, *69*(6), 44–49. https://doi.org/10.1080/00043125.2016.1224873

Morris, T. H. (2020). Experiential learning – a systematic review and revision of Kolb's model. *Interactive Learning Environments*, *28*(8), 1064–1077. https://doi.org/10.1080/10494820.2019.1570279

Moser, A., and Korstjens, I. (2018). Series: Practical guidance to qualitative research. Part 3: Sampling, data collection and analysis. *European Journal of General Practice*, *24*(1), 9–18. https://d–oi.org/10.1080/13814788.2017.1375091

Perignat, E., and Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature review. *Thinking Skills and Creativity*, *31*, 31–43. https://doi.org/10.1016/j.tsc.20–18.10.002

Rahmadi, I. F., and Lavicza, Z. (2021). Pedagogical Innovations in Elementary Mathematics Instructions: Future Learning and Research Directions. *International Journal on Social and Education Sciences*, *3*(2), 360–378.

Rogers, E. M. (2003). *Diffusion of Innovations* (5th ed). Free Press.

Shernoff, D. J., Sinha, S., Bressler, D. M., and Ginsburg, L. (2017). Assessing teacher education and professional

development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education*, *4*(1), 13. https://doi.org/10.1186/s40594-017-0068-1

Stebbins, R. A. (2001). *Exploratory Research in the Social Sciences*. SAGE.

https://dx.doi.org/10.4135/9781412984249

van Driel, J. H., Verloop, N., and de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching*, *35*(6), 673–695. https://doi.org/10.10–02/(SICI)1098-2736(199808)35:6<673:AID-TEA5>3.0.CO;2-J

Yakman, G., and Lee, H. (2012). Exploring the Exemplary STEAM Education in the U.S. as a Practical Educational Framework for Korea. *Journal of The Korean Association For Science Education*, *32*(6), 1072–1086. https://doi.org/10.14697/JKASE.2012.32.6.1072

Author:

Yudi Yunika Putra, M.Pd
Lecturer, Department of Mathematics Education, Faculty of Teacher Training and Education, Universitas Muhammadiyah Bangka Belitung, Jl. KH A Dahlan, Pangkal Pinang, Bangka Belitung, Indonesia, email: yudi.yunikaputra@unmuhbabel.ac.id
Predavatelj, Oddelek za didaktiko matematike, Fakulteta za izobraževanje učiteljev, Univerza Muhammadiyah Bangka Belitung, Jl. KH A Dahlan, Pangkal Pinang, Bangka Belitung, Indonezija, e-pošta: yudi.yunikaputra@unmuhbabel.ac.id

Vika Martahayu, M.Pd
Lecturer, Primary Teacher Education, Faculty of Teacher Training and Education, Universitas Muhammadiyah Bangka Belitung, Jl. KH A Dahlan, Pangkal Pinang, Bangka Belitung, Indonesia, email: vika.martahayu@unmuhbabel.ac.id
Predavateljica, Izobraževanje učiteljev razrednega pouka, Fakulteta za izobraževanje učiteljev, Univerza Muhammadiyah Bangka Belitung, Jl. KH A Dahlan, Pangkal Pinang, Bangka Belitung, Indonezija, e-pošta: vika.martahayu@unmuhbabel.ac.id

Imam Fitri Rahmadi, PhD
Lecturer, Faculty of Education, Universitas Negeri Jakarta, Jl. R.Mangun Muka Raya, Rawamangun, Pulo Gadung, Jakarta Timur, Indonesia, email: imam.rahmadi@unj.ac.id
Predavatelj, Pedagoška fakulteta, Univerza Negeri Jakarta, Jl. R. Mangun Muka Raya, Rawamangun, Pulo Gadung, Vzhodna Jakarta, Indonezija, e-pošta: imam.rahmadi@unj.ac.id

Joko Sutrisno AB, M.Pd, PhD
Associate professor, Mathematics Education Department, STKIP PGRI Bandar Lampung, Jl. Chairil Anwar, Bandar Lampung, Indonesia, email: joko_sutrisno_ab@stkippgribl.ac.id
Izredni profesor, Oddelek za didaktiko matematike, STKIP PGRI Bandar Lampung, Jl. Chairil Anwar, Bandar Lampung, Indonezija, e-pošta: joko_sutrisno_ab@stkippgribl.ac.id

Houssam Kasti, PhD
Lecturer, General Education Department, Qatar University, Al-Jamiaa Street, Doha, Qatar, email: helkasti@qu.edu.qa
Predavateljica, Oddelek za splošno izobraževanje, Univerza Katar, Al-Jamiaa Street, Doha, Katar, e-pošta: helkasti@qu.edu.qa

.