Journal of Education and Learning (EduLearn)
Vol. 20, No. 2, May 2026, pp. 887~894
ISSN: 2089-9823, DOI: 10.11591/edulearn.v20i2.23186

The impact of PBL STEAM model of light and optics on problem-solving skill of pre-service science teachers

Sumalee Tientongdee[1], Porntida Visaetsilapanonta[2]
[1]General Science Program, Faculty of Education, Suan Sunandha Rajabhat University, Bangkok, Thailand
[2]Department of Education, Faculty of Social Sciences and Humanities, Mahidol University, Bangkok, Thailand

Article Info

Article history:

Received Aug 30, 2024
Revised Jun 16, 2025
Accepted Jul 19, 2025

Keywords:

Light and optics
Pre-service science teacher
Problem-based learning
Problem-solving skill
STEAM education

ABSTRACT

This research was to study the effects of a learning model using problem-based learning (PBL) with science, technology, engineering, arts, and mathematics (STEAM) education of light and optics topics on pre-service science teachers' learning achievement and problem-solving skills. The data were collected using mixed methods for 15 weeks from December 2023 to March 2024. The sample group was 30 undergraduates majoring in teaching general science and taking physics for teacher courses. The achievement test and problem-solving skill evaluation form were used before and after participating in five lesson plans of the PBL with STEAM model focusing on the content of light and optics. This model consists of six steps: i) finding interesting problems; ii) identifying a problem to solve within the group; iii) planning the design; iv) conducting the PBL with STEAM project; v) modifying the project; and vi) project presentation. The results indicated that their learning outcomes of light and optics in physics and problem-solving skills were significantly higher after learning through this model. The results are similar to previous research on PBL and STEAM education at all levels. It is suggested that future studies should focus on applying PBL with STEAM projects to the real science classrooms in the middle school level and providing more time on project designing process.

Corresponding Author:

Sumalee Tientongdee
General Science Program, Faculty of Education, Suan Sunandha Rajabhat University
U-Thongnok Road No. 1, Dusit, Bangkok, Thailand
Email: sumalee.ti@ssru.ac.th

1. INTRODUCTION

Educational systems worldwide are increasingly emphasizing the development of learners' competencies in critical thinking, creativity, communication, and collaboration to address the complexities of modern society [1]. Many leading countries recognize that science education must evolve beyond traditional content delivery to incorporate real-world problem-solving and interdisciplinary learning experiences. In Asian regions, these trends have heightened the urgency to reform science curricula and pedagogical approaches. Thailand, for instance, has highlighted the importance of 21st-century skills, including the ability to tackle complex problems, think critically, communicate effectively across diverse cultures, and work collaboratively under rapidly shifting conditions. The Thai government and the Education Ministry will solve the problem as quickly as possible to achieve tangible results on science, mathematics, and reading literacy. In the 2025 assessment, Thai student's rankings must improve in science and mathematics achievement. Addressing these demands requires preparing future science teachers who are both knowledgeable and adept at implementing innovative instructional models to be focused on science, technology, engineering, and mathematics (STEM) education [2].

The integration of STEAM education with problem-based learning (PBL) has emerged as a promising strategy for enhancing science instruction [3]. Such an approach allows pre-service teachers to gain both the content and pedagogical knowledge necessary for effective science teaching [4]. By fostering problem-solving abilities and interdisciplinary thinking, PBL and STEAM can help pre-service teachers acquire the skills needed to design and facilitate learning experiences that engage students in authentic scientific inquiries [5]. Prior research has shown that effective teacher preparation in these domains leads not only to improved teacher satisfaction, but also to enhanced student achievement and deeper conceptual understanding [6], [7]. Moreover, studies have indicated that STEAM-based instruction can cultivate essential 21st-century competencies, resulting in significant learning gains, including improved thinking skills [8]. The implementing STEAM education in schools positively affected learners' learning achievement, and development skills. As a result, STEAM education can help learners develop their learning outcomes [9].

Within the domain of physics education, concepts such as light and optics often pose considerable challenges for learners [10]. Problem-solving difficulties may arise from gaps in mathematical skills, limited conceptual understanding, or a lack of exposure to real-world applications of physics principles. Consequently, pre-service teachers must develop the capacity to effectively teach these topics using methods that emphasize inquiry, design, and iteration [11]. Research suggests that PBL, supported by STEAM initiatives, can foster learning environments where students engage deeply with scientific phenomena, thereby improving their problem-solving proficiencies and overall achievement [12]. Studies integrating PBL into science education have reported increased learner satisfaction, enhanced scientific literacy, and better conceptual grasp in physics-related content [13].

The integration of PBL and STEAM provides an effective framework for interdisciplinary learning, allowing pre-service teachers to design and implement instructional models that bridge the gap between theoretical concepts and practical applications [14]. By structuring lessons around real-world problems, this approach enables learners to make meaningful connections between science, technology, engineering, mathematics, and artistic creativity. Pre-service teachers trained in such an environment develop the ability to facilitate student-centered learning experiences, foster collaboration, and encourage inquiry-based problem-solving. Moreover, the interdisciplinary nature of STEAM enhances students' ability to visualize the interconnectedness of different fields, promoting a holistic understanding of scientific and technological advancements [15].

Despite the growing body of research on the effectiveness of PBL and STEAM integration in science education, a critical gap remains in understanding how these approaches specifically impact pre-service teachers' learning outcomes and teaching competencies, particularly in physics-related topics such as light and optics. This study aims to address this gap by investigating how a PBL-based STEAM instructional model influences pre-service science teachers' conceptual understanding, problem-solving skills, and pedagogical readiness in teaching light and optics [16]. By focusing on this intersection, the research contributes valuable insights for teacher education programs and curriculum designers seeking to empower future educators with innovative and effective instructional techniques.

Ultimately, this study not only aligns with global educational priorities but also holds significant implications for improving the quality and relevance of science education in Asian contexts and beyond. By equipping pre-service teachers in science with the ability to implement PBL and STEAM-based instructional strategies, this research supports the broader goal of fostering a new generation of educators capable of preparing students for the demands of a rapidly evolving world. Also, to encourage all pre-service teachers to understand and integrate all related fields in STEAM into a real-world problem and be able to apply in their own science classroom in the future.

2. METHOD

In this research, five lesson plans were developed based on a PBL with STEAM model, employing light and optics topics for pre-service science teachers. The model encompassed six steps in the learning process: i) finding interesting problems; ii) identifying a problem to solve within the group; iii) planning the design; iv) conducting the PBL with STEAM project; v) modifying the project; and vi) presenting the project. These six integrated steps were designed to foster interdisciplinary learning. Following the methodology proposed by Durakovic [12], this six-step PBL with STEAM model was introduced to improve both the learning outcomes and problem-solving skills of pre-service science teachers in physics-related concepts.

An experimental, pre-test/post-test design was employed to evaluate the effectiveness of this model. The study focused on enhancing participants' learning achievement and problem-solving abilities, as measured by an achievement test and a problem-solving evaluation form. Figure 1 illustrates the research design and evaluation framework.

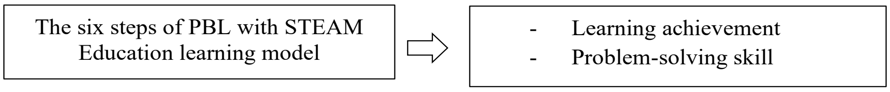

Figure 1. The research framework of the study

2.1. Population and sample

The population of this study comprised 60 first-year undergraduate pre-service science teacher students enrolled in the Faculty of Education at Suan Sunandha Rajabhat University, Bangkok, Thailand, during the 2023 academic year. They were divided into two sections based on the requirement of the Teachers' Council of Thailand regulations. Therefore, we considered these sections as equally groups. The cluster random sampling and convenience selection [17] were employed to select one section as a sample group of 30 participants. These selected students were enrolled in the "physics for science teacher II" course in the second semester, which took place from December 2023 to March 2024. The undergraduates of this Bachelor degree in Education Program came from difference areas all over the country. They were accepted by the Thailand national admission process for teachers.

2.2. Instruments

The research utilized two primary instruments: i) learning outcomes test with multiple-choice test covering light and optics concepts, designed to measure pre-service science teachers' conceptual understanding. each item was aligned with specific learning objectives, ensuring content validity; and ii) problem-solving skills assessment with rubric-based evaluation assessing essential dimensions of problem-solving such as problem identification, approach, content application, data analysis, and communication applied to project-based tasks. The content validity of the instrument used in this study was reviewed by experts in science education and PBL, who ensured that the instrument comprehensively assessed all relevant aspects of the construct being measured, including knowledge and skills related to light and optics, as well as problem-solving and collaboration within the STEAM framework. These experts confirmed that the instrument reflects all necessary content. Pilot test the questionnaire with a pilot group the reliability value Cronbach's alpha is equal to 0.92.

2.3. Data analysis

This study utilized descriptive statistics to summarize the general characteristics of the participants. To assess the effectiveness of the PBL and STEAM learning model, inferential statistical methods were applied. Specifically, a t-test was conducted to compare the pre-test and post-test scores of pre-service science teachers, measuring their learning outcomes and problem-solving abilities before and after engaging with the PBL and STEAM learning model. This analytical approach allowed for a systematic assessment of how the instructional model influenced both academic achievement and problem-solving skills, providing quantitative evidence of its impact.

3. RESULTS AND DISCUSSION

In the research findings are presented in two sections, aligned with the research objectives. The first section addresses the pre-service science teachers' learning outcomes on light and optics concepts, and the second section focuses on the improvement of their problem-solving skills.

3.1. Pre-service science teacher learning outcome improvement

Their learning outcome comparisons, both before and after exposure to the PBL with STEAM education model, are summarized in Table 1. These findings are based on a multiple-choice test covering light and optics content, which was verified for high reliability and appropriate discrimination indices. Descriptive statistics were employed to present general information about the participants, while inferential statistics facilitated the comparison of pre-test and post-test scores. Specifically, a t-test was conducted to evaluate differences in the pre-service science teachers' learning outcomes before and after the intervention, as well as to analyze their problem-solving abilities following participation in this learning model.

Table 1. Comparison of pre-service science teachers' learning outcome on light and optics

Test	Mean	SD	t	p
Pre-test	11.00	2.83	53.87	0.00*
Post-test	26.27	0.62		

Note: *Significant level 0.05

The results presented in Table 1 indicate that the pre-service science teachers attained a significantly higher mean score of 26.27 (SD=0.62) following the PBL with STEAM intervention. The decrease in the standard deviation (SD) from the pre-test to the post-test suggests that their performance scores converged toward the mean, reflecting a more uniform improvement in learning outcomes. These findings are consistent with prior research demonstrating that PBL activities can enhance teaching efficiency and learning achievement in higher education settings [18].

Similar improvements have been observed in physics education, where students' academic achievement and conceptual understanding increased in proportion to the number of physics problems solved using PBL strategies [19]. A qualitative component of a previous study revealed that students who were aware of being observed during problem-solving tasks exhibited enhanced performance, likely due to increased focus and the metacognitive awareness of their own processes. Moreover, the integration of STEAM into science classrooms has been shown to further elevate students' achievement in various STEM-related subjects [20]. These mean they can apply light and optics topic in physics with technology into engineering design and using mathematics to help designing their projects as well.

3.2. Pre-service science teacher problem-solving skill

The pre-service science teachers' problem-solving skills were assessed using a rubric-based evaluation form both before and after their participation in the six-step PBL with STEAM learning model. A t-test was conducted to compare the pre-test and post-test scores, and the results are presented in Table 2. According to the results presented in Table 2, the pre-service science teachers' problem-solving skills improved significantly after participating in the PBL with STEAM learning model. Their post-intervention mean score reached 24.10 with a SD of 1.61, compared to a pre-intervention mean score of 10.03 (SD=2.17). Notably, the reduced SD in the post-test suggests a more uniform enhancement of problem-solving abilities among the participants. These findings align with educational policies emphasizing the development of problem-solving skills as a fundamental 21st-century competency. Their problem-solving scores were shown obvious improvement after learning through this six-step PBL with STEAM.

Table 2. Comparison of pre-service science teachers' problem-solving skill

Test	Mean	SD	t	p
Pre-test	10.03	2.17	59.97	0.00*
Post-test	24.10	1.61		

Note: *Significant level 0.05

Problem-solving is recognized as a critical component of physics education and was therefore a focal point of this study. The approach allowed pre-service teachers to work collaboratively in small groups, identify intriguing problems, and plan solutions by integrating STEAM. Similar results have been reported in prior studies, indicating that a PBL environment encourages students to take ownership of their learning, engage actively with content, and collaboratively resolve authentic problems [21], [22]. Moreover, research has demonstrated that combining PBL with STEAM approaches can strengthen learners' competencies in physics, particularly in challenging domains such as light and optics [23]. Previous studies also confirm that using real-world STEAM problems can foster interdisciplinary thinking and enhance both learning achievement and problem-solving skills [24]. The present study's findings are consistent with this body of research, underscoring the potential of PBL with STEAM to improve undergraduate students' physics proficiency.

3.3. Pre-service science teacher PBL with STEAM education projects

The pre-service science teachers collaborated in teams during steps 3 through 6 of the learning process, wherein they conducted their projects. Similar research indicates that integrating STEAM into science classrooms can enhance students' efficiency in collaboratively creating scientific projects [25]. In the present study, a key difference was the deliberate inclusion of the "arts" component, which encouraged the pre-service teachers to jointly identify engaging problems and to plan their solutions through STEAM principles. These findings are in agreement with previous studies that underscore the value of incorporating interdisciplinary approaches into teacher preparation [26]–[28]. After refining their projects, not only emphasize on their learning achievement, but also problem-solving skill based on Figure 1. The teams had presented their final work projects. Therefore, examples of STEAM projects are illustrated in Figure 2, it shows pictures of student STEAM education projects consisting of Figure 2(a) fun with mirror reflection and Figure 2(b) refraction coloring.

(a) (b)

Figure 2. Student STEAM education projects (a) fun with mirror reflection and (b) refraction coloring

The influence of the PBL with STEAM learning model on learners' problem-solving abilities parallels earlier findings that a PBL-STEAM approach can enhance creative thinking in environmental pollution contexts [29], [30]. Our results likewise indicate that undertaking interdisciplinary projects within a STEAM framework not only improves problem-solving skills but also increases students' interest in physics and other STEM fields. Previous research supports this conclusion, showing that implementing STEAM-integrated project-based learning enhances students' performance in conducting projects [31]. Similarly, interdisciplinary STEAM curricula have been shown to strengthen students' project competence and elevate their motivation to learn. Moreover, the pre-service science teachers in this study reported a high level of satisfaction toward science after participating in the PBL with STEAM learning model. They recognized the value of science in their daily lives, a finding consistent with earlier work to improve their attributes toward physics [32]. Such outcomes underscore the potential of PBL with STEAM to develop scientifically literate individuals who value and apply scientific understanding to real-world challenges. Their attitudes toward science based on classroom observation during the activities were very positive and engaging.

4. CONCLUSION

This study highlights the effectiveness of integrating PBL with STEAM education, particularly in preparing future science teachers. By fostering interdisciplinary learning and critical 21st-century skills, the research demonstrates the potential of innovative pedagogical approaches to enhance both learning outcomes and problem-solving abilities among pre-service educators. In this study, five lesson plans were developed following six structured learning steps: i) finding interesting problems; ii) identifying a problem to solve within the group; iii) planning the design; iv) conducting the PBL with STEAM project; v) modifying the project; and vi) project presentation. Implemented with 30 pre-service science teachers using light and optics topics, the intervention resulted in a significantly higher mean achievement score of 26.27 (SD=0.62) and a notably enhanced mean problem-solving score of 24.10 (SD=1.61). The combination of PBL with STEAM promotes deeper engagement with complex issues, encouraging collaboration, creativity, and the application of interdisciplinary knowledge. These findings demonstrate that the PBL with STEAM learning model not only improves conceptual understanding and subject mastery in physics but also encourages collaborative problem-solving and creativity and attitudes toward science. The integration of STEAM within a PBL framework enables learners to engage deeply with complex issues, applying interdisciplinary knowledge and skills effectively.

It is recommended to explore the development of e-learning materials aligned with the PBL with STEAM model, which could extend its application to online learning environments in digital world. Additionally, employing this model across various levels of science teaching methods could help students better integrate STEAM subjects with career decision-making processes related to science areas, supporting their navigation of both academic and professional pathways. Further investigations should focus on the adaptability and effectiveness of the STEAM-integrated PBL approach across a broader range of educational levels especially in primary level, including different cultural, digital, and geographical contexts. Such research would provide understanding into how the approach can be tailored for learner populations, ensuring that its benefits are universally applicable. Longitudinal studies would also be valuable in assessing the long-term impact of this model on science educators' professional development and classroom practices after their training. Moreover, future research should explore how the integration of STEAM disciplines affects critical areas such as problem-solving skills, motivation, creativity, and overall engagement in science education. These insights would be crucial for curriculum designers and policymakers, allowing them to refine the model and ensure it not only enhances academic outcomes but also inspires students to become active, innovative contributors to the scientific community. By addressing these research directions, the PBL with STEAM approach could be further developed, providing a robust framework for preparing educators who can inspire the next generation of problem-solvers, innovators, and scientists.

ACKNOWLEDGMENTS

Author thanks the experts who helped verify the research instruments and the faculty members at Suan Sunandha Rajabhat University and Mahidol University for supporting the data collection and analysis process. The researchers thank the institute of research and development, Suan Sunandha Rajabhat University for supporting on IRB consideration.

FUNDING INFORMATION

This research has no funding involved.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Sumalee Tientongdee	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Porntida Visaetsilapanonta	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that we have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Authors state no conflict of interest.

INFORMED CONSENT

This study was to improve learning and teaching. We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

This study has been approved by the authors' institutional review board committee of Suan Sunandha Rajabhat University.

DATA AVAILABILITY

Due to confidentiality and privacy agreements with the participants, the data that support the findings of this study are available on request from the corresponding author, [ST], upon reasonable request.

REFERENCES

[1] J. Sun, "Implementing and facilitating STEAM problem-based learning from the perspective of teacher leadership," *Asia Pacific Journal of Educators and Education*, vol. 38, no. 2, pp. 221–248, Dec. 2023, doi: 10.21315/apjee2023.38.2.12.

[2] G. Ubben, "Using project-based learning to teach STEAM," in *Converting STEM into STEAM Programs: Methods and Examples from and for Education*, A. J. Stewart, M. P. Mueller, and D. J. Tippins, Eds., Cham: Springer International Publishing, 2019, pp. 67–83, doi: 10.1007/978-3-030-25101-7_6.

[3] M. Giampaolo and L. Fabbri, "Online problem based learning for the professional development of educators," in *International Workshop on Higher Education Learning Methodologies and Technologies Online (HELMeTO 2019)*, 2019, pp. 41–53, doi: 10.1007/978-3-030-31284-8_4.

[4] S. Belbase, B. R. Mainali, W. Kasemsukpipat, H. Tairad, M. Gochoo, and A. Jarrah, "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,* vol. 53, no. 11, pp. 2919–2955, May. 2021, doi: 10.1080/0020739X.2021.1922943.

[5] A. C. K. Cheung, "Teacher STEAM education supported by professional learning communities: a meaningful practice of teacher professional development," *Science Insights Education Frontiers*, vol. 20, no. 1, pp. 3117–3119, Jan. 2024, doi: 10.15354/sief.24.co249.

[6] N. Karmila, I. Wilujeng, and H. Sulaiman, "The effectiveness of problem based learning (PBL) assisted google classroom to scientific literacy in physics learning," in *Proceedings of the 6th International Seminar on Science Education (ISSE 2020)*, 2021, pp. 447–452, doi: 10.2991/assehr.k.210326.064.

[7] I. Yoon and M. Kim, "Dynamic patterns of teachers' professional development participation and their relations with socio-demographic characteristics, teacher self-efficacy, and job satisfaction," *Teaching and Teacher Education*, vol. 109, p. 103565, Jan. 2022, doi: 10.1016/j.tate.2021.103565.

[8] A. K. Segarra-Morales and M. Juca-Aulestia, "Strategies and skills in STEAM education systematic review of the literature," in *International Conference on Information Technology & Systems (ICITS 2024)*, 2024, pp. 398–411, doi: 10.1007/978-3-031-54235-0_36.

[9] A. K. Amanova, L. A. Butabayeva, G. A. Abayeva, A. N. Umirbekova, S. K. Abildina, and A. A. Makhmetova, "A systematic review of the implementation of STEAM education in schools," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 21, no. 1, p. em2568, Jan. 2025, doi: 10.29333/ejmste/15894.

[10] E. Ahdhianto, M. Marsigit, H. Haryanto, and Y. Nurfauzi, "Improving fifth-grade students' mathematical problem-solving and critical thinking skills using problem-based learning," *Universal Journal of Educational Research*, vol. 8, no. 5, pp. 2012–2021, May 2020, doi: 10.13189/ujer.2020.080539.

[11] S. Annamdevula and R. S. Bellamkonda, "The effects of service quality on student loyalty: the mediating role of student satisfaction," *Journal of Modelling in Management*, vol. 11, no. 2, pp. 446–462, May 2016, doi: 10.1108/JM2-04-2014-0031.

[12] A. Durakovic, "A research of middle school students' attitudes towards STEM education in terms of some variables: which variables had the greatest impact on attitudes?" *International Online Journal of Education and Teaching (IOJET)*, vol. 9, no. 2, pp. 1032–1046, 2022.

[13] Parno, L. Yuliati, F. M. Hermanto, and M. Ali, "A case study on comparison of high school students' scientific literacy competencies domain in physics with different methods: PBL-STEM education, PBL, and conventional learning," *Jurnal Pendidikan IPA Indonesia*, vol. 9, no. 2, pp. 159–168, Jun. 2020, doi: 10.15294/jpii.v9i2.23894.

[14] X. Huang, S. Erduran, P. Zhang, K. Luo, and C. Li, "Enhancing teachers' STEM understanding through observation, discussion and reflection," *Journal of Education for Teaching*, vol. 48, no. 5, pp. 576–591, Oct. 2022, doi: 10.1080/02607476.2021.2006571.

[15] B. T. M. Wong and R. Kwan, "Latest advances in STEAM education research and practice: a review of the literature," *International Journal of Innovation and Learning*, vol. 29, no. 3, pp. 323–339, 2021, doi: 10.1504/IJIL.2021.10036022.

[16] N. Folomieieva, O. Koriakin, L. Matsenko, I. Siaska, and I. Fed, "Problem-based learning in higher education: a path towards training innovative and competent specialists," *Revista Amazonia Investiga*, vol. 13, no. 77, pp. 201–217, May 2024, doi: 10.34069/AI/2024.77.05.15.

[17] C. Andrade, "The inconvenient truth about convenience and purposive samples," *Indian Journal of Psychological Medicine*, vol. 43, no. 1, pp. 86–88, Jan. 2021, doi: 10.1177/0253717620977000.

[18] M.-L. Hung and C.-W. Tsai, "Problem-based learning in teacher education," *Higher Education Research & Development*, vol. 39, no. 5, pp. 1070–1074, Jul. 2020, doi: 10.1080/07294360.2019.1675946.

[19] H. Durasa, N. M. S. Mertasari, and I. G. N. Pujawan, "Improve problem-solving ability through implementation of problem-based learning based on self-regulation," *Mathema: Jurnal Pendidikan Matematika*, vol. 6, no. 2, pp. 491–501, Jul. 2024, doi: 10.33365/jm.v6i2.3905.

[20] K. L. Boice, J. R. Jackson, M. Alemdar, A. E. Rao, S. Grossman, and M. Usselman, "Supporting teachers on their STEAM journey: a collaborative STEAM teacher training program," *Education Sciences*, vol. 11, no. 3, p. 105, Mar. 2021, doi: 10.3390/educsci11030105.

[21] A. Budarina, O. Parakhina, and K. Degtyarenko, "STEAM-approach to teacher training at the Immanuel Kant Baltic Federal University," in *ARPHA Proceedings*, Feb. 2022, pp. 193–204, doi: 10.3897/ap.5.e0193.

[22] A. Suryanda, M. Miarsyah, and A. H. U. A. Kosasih, "Improving creative thinking skills through integration of problem-based learning with STEAM in environmental pollution material," *Jurnal Penelitian Pendidikan IPA*, vol. 9, no. Special Issue, pp. 184–190, Dec. 2023, doi: 10.29303/jppipa.v9iSpecialIssue.4524.

[23] A. A. Chistyakov, S. P. Zhdanov, E. L. Avdeeva, E. A. Dyadichenko, M. L. Kunitsyna, and R. I. Yagudina, "Exploring the characteristics and effectiveness of project-based learning for science and STEAM education," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 19, no. 5, p. em2256, May 2023, doi: 10.29333/ejmste/13128.

[24] C.-L. Lin and C.-Y. Tsai, "The effect of a pedagogical STEAM model on students' project competence and learning motivation," *Journal of Science Education and Technology*, vol. 30, no. 1, pp. 112–124, Feb. 2021, doi: 10.1007/s10956-020-09885-x.

[25] T. J. McConnell, J. M. Parker, and J. Eberhardt, "Problem-based learning for responsive and transformative teacher professional development," *Global Journal of Transformative Education*, vol. 1, no. 1, pp. 18–25, Jan. 2019, doi: 10.14434/gjte.v1i1.25848.

[26] V. Hlukhaniuk, V. Solovei, S. Tsvilyk, and I. Shymkova, "STEAM education as a benchmark for innovative training of future teachers of labour training and technology," in *Society. Integration. Education. Proceedings of the International Scientific Conference*, May 2020, pp. 211–221, doi: 10.17770/sie2020vol1.5000.

[27] S. K. Pant, B. C. Luitel, and B. P. Pant, "STEAM pedagogy as an approach for teacher professional development," *Mathematics Education Forum Chitwan*, vol. 5, no. 5, pp. 28–33, Dec. 2020, doi: 10.3126/mefc.v5i5.34760.

[28] N. Spyropoulou and A. Kameas, "Augmenting the impact of STEAM education by developing a competence framework for STEAM educators for effective teaching and learning," *Education Sciences*, vol. 14, no. 1, p. 25, Dec. 2023, doi: 10.3390/educsci14010025.

[29] K. Koh and O. Chapman, "Problem-based learning, assessment literacy, mathematics knowledge, and competencies in teacher education," *Papers on Postsecondary Learning and Teaching*, vol. 3, pp. 74–80, Apr. 2019, doi: 10.55016/ojs/pplt.v3Y2019.53141.

[30] Nurhasnah, Festiyed, and Yerimadesi, "A review analysis: implementation of STEAM project based learning in science learning," *SEJ (Science Education Journal)*, vol. 7, no. 1, pp. 1–13, May 2023, doi: 10.21070/sej.v7i1.1623.

[31] W. Hehakaya, M. N. Matdoan, and D. Rumahlatu, "Integrating STEAM with PjBL and PBL on biology education: Improving students' cognitive learning results, creative thinking, and digital literacy," *Boisfer: Jurnal Pendidikan Biologi,* vol. 15, no. 1, pp. 76–84*,* Feb. 2022*,* doi: 10.21009/biosferjpb.24468.

[32] C. Conradty and F. X. Bogner, "STEAM teaching professional development works: effects on students' creativity and motivation," *Smart Learning Environments*, vol. 7, no. 1, p. 26, Dec. 2020, doi: 10.1186/s40561-020-00132-9.

BIOGRAPHIES OF AUTHORS

Sumalee Tientongdee is an associate professor in teaching science. She received her Doctoral degree in Science Education and Master degree in Physics. In 2016 she joined the General Science Program, Faculty of Education, Suan Sunandha Rajabhat University, Thailand. She has written several papers in the areas of science teaching, teacher training, physics education, engineering design, and STEM education. Her research interests also include STEAM education and training, higher-order thinking, and teacher development. She has held administrative posts as school director at demonstration school of Suan Sunandha Rajabhat University. She previously held the position as assistant to the president in academic affair and head of general science program at Suan Sunandha Rajabhat University. Her contributions to the current paper align with her expertise in teacher training and STEM education, offering valuable perspectives on effective instructional strategies and curriculum development. Her work continues to support innovative teaching methodologies and the professional development of educators in science and engineering education. She can be contacted at email: sumalee.ti@ssru.ac.th.

Porntida Visaetsilapanonta is educator and researcher in population education and evaluation research. She is affiliated with the Department of Education, Faculty of Social Sciences and Humanities at Mahidol University. She has researched extensively and has widely published in the areas of assessment, research methodology, teacher development, and STEM education. She has held administrative posts as head of Department of Education for several years. At the national level, she serves as research funded on STEM development for science teachers in Thailand. Her contributions to the current paper build upon her expertise in research methodology and STEM education, offering insights into effective pedagogical strategies and assessment frameworks. Her work continues to shape teacher training programs and education policies, particularly in STEM-related disciplines. She can be contacted at email: porntida.vis@mahidol.ac.th.