Transforming Education: Using the Pedagogy, Spaces and Technology (oPSTi) Framework to Teach Project Based Learning Among Southeast Asia Educators

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Abstract
Digital citizenship encompasses interaction via the network, appropriate learning spaces and suitable technology tools in an emerging trend in STEM education. The digital literacies comprise the teaching and learning skills that enable technology to emerge in teaching and learning. This article examines the transformative impact of the Pedagogy, Spaces, and Technology (oPSTi) Framework on teaching and learning among educators in Southeast Asia. The study employed a case study research design using post-test questionnaire. Twenty-four educators from Southeast Asian were involved in the purposive sampling to identify the impact of the oPSTi framework in teaching and learning. The findings reveal a significant enhancement in teaching practices, experiences, and confidence among these educators following their engagement using the oPSTi Framework in the workshop. The findings indicated the key pedagogical strategies and innovative teaching activities, which were highly effective, with a mean value ranging from 4.41 to 4.68. The framework's emphasis on self-determined learning, adult learning principles, and project-based learning with the application of digital learning tools was pivotal in this enhancement. Notably, the use of technology tools, both hardware and software, enabled effective integration of coding and computational thinking skills using Magnetcode. The respondents reported increased motivation and a greater propensity to recommend the oPSTi Framework to their peers, highlighting its potential to drive substantial improvements in educational practices. The study underscores the oPSTi Framework's capacity to foster a dynamic and effective teaching environment, aligning with the current trends in digitalization of STEM education. This transformation is crucial for equipping educators with the skills and confidence needed to integrate coding and programming into their teaching practices, ultimately contributing to the broader advancement of STEM education in the region.

Keywords: oPSTi Framework, Magnetcode Application, Microcontroller, STEM Education, Southeast Asian Educators

Introduction

In the rapidly evolving educational landscape, digital citizenship and STEM (Science, Technology, Engineering, and Mathematics) education have become crucial components (Economic Planning Unit, 2021). Integrating technology into teaching not only enhances learning experiences but also prepares educators for a technologically advanced future (Qismullah & Yunisrina, 2018). The integration of digital culture in education is a cornerstone of teaching innovation, as highlighted by recent studies on digital education (Cerstin & Andreas, 2019). The pivotal role of digital technology in moving away from traditional models has been especially significant in remote learning environments, bringing attention to training spaces, digital skills, and learning methods(Mason & Rich, 2019; Mattila et al., 2022). This shift has reignited the potential of digital technology, as emphasized in recent STEM educational (Norhaqikah & Kamisah, 2017; Yean & Abdul Rahim, 2021). STEM education has many advantages as it is an innovative and attractive tool for teaching and learning (Suryani et al., 2024). It is an exciting field for children to satisfy their curiosity about the world (Hsieh et al., 2022).

STEM education in Southeast Asia faces several significant challenges in both teaching and learning (Faikhamta et al., 2020). One major issue is the outdated curriculum that many educational institutions still rely on, which fails to reflect the latest advancements in STEM fields (Stamatios et al., 2023). Additionally, the curriculum often lacks contextual relevance, making it difficult for teachers to connect with subject based contents(Blackley & Howell, 2019; García-Peñalvo, 2018). Pedagogically, the reliance on teacher-centered methods, such as lecture-based teaching, limits student engagement and critical thinking. Furthermore, there are limited opportunities for educators to participate in ongoing professional development to update their skills and knowledge in STEM education (Khairani, 2017). This professional stagnation contributes to a lack of student interest in STEM subjects, partly because they are perceived as difficult and uninteresting (Nik Hazimin & Hazrati, 2019).

The adoption of technology tools in STEM education presents its own set of challenges among Southeast Asian teachers (Susilo & Sudrajat, 2020). Teachers face challenge in integration of the learning space physically and virtually which is technological infrastructure, and inconsistent internet connectivity further hampers the effective use of online learning tools (Sastra et al., 2021). Teacher preparedness is another critical issue, as many educators are not adequately trained to integrate technology into their teaching practices effectively (Siti Noor Aneeis et al., 2022; Yeh & Tsai, 2022). This lack of technological literacy (Wu & Anderson, 2015), combined with resistance to change due to unfamiliarity with digital tools, further complicates the adoption process. Additionally, limited financial resources restrict the acquisition of up-to-date technology and software necessary for effective STEM education. The scarcity of high-quality, localized digital educational content and tools also hampers the ability to cater to the specific needs of Southeast Asian students (Daugherty Michael & Carter, 2019; Hidiroğlu & Karakaş, 2022; Lakshminarayanan & McBride, 2015).

Addressing these issues requires a comprehensive approach involving teaching and learning strategies in STEM education embedded with learning space and technology. The researcher aim to assess the impact of the oPSTi framework in term of pedagogy, learning space and technology to enhance the quality of STEM education and better prepare students for the demands of the modern workforce.

Research Objective

To assess the impact of the oPSTi Framework on teaching and learning among Southeast Asian educators.

Research Question

What is the impact of the oPSTi framework on teaching and learning among Southeast Asian educators?

Literature Review

The oPSTi framework is a conceptual map for planning or revising any teaching, learning or lesson. It can be easily adapted and mixed with the elements in the framework. The oPSTi framework was developed through the design and development research (DDR) using the experts consensus for the constructs and elements (Sanura et al., 2022). The Pedagogy-Space-Technology (PST) is the existing framework from Carrick Institute by Professor Radcliffe for the Next Generation Learning Spaces project at the University of Queensland (Radcliffe et al., 2008a, 2008b). The learning environment originated from three interdependent aspects: pedagogy, space and technology (Fisher, 2005; Oblinger, 2005). Earlier scholars, Wilson, Powell and Tibbetts (2008) implied "a nexus between pedagogy, the design of the learning spaces and technology and suggested the PST framework as guidelines in NGLS to enhance 21st-century skill in era 5.0. The transition from PST framework have been improved with development of the oPSTi framework with the strength in emergence the elements of pedagogy in innovative ways, application of the technology and suitable learning space by looking into the objective and implementation of the framework in teaching and learning (Sanura et al., 2022). Figure 1 illustrated the existing framework and oPSTi framework. The outdoor classroom environment and the utilization of space will influence the preferred teaching methods and technology for both teachers and students in next-generation education as illustrated in Figure 1.

(a) (b)

Figure 1: (a) The Transition From Existing Framework
(b) PST Framework to oPSTi Framework
Sources: (Radcliffe, 2008) and (Sanura, 2023)

Figure 1 illustrated the transition from the existing PST (Pedagogy, Space, Technology) (Radcliffe et al., 2008a) framework to the new oPSTi framework represents a significant evolution in educational methodology. While the existing PST framework focuses on integrating traditional teaching methods, learning environments, and basic technological tools, the oPSTi framework enhances these elements with a more dynamic and interactive approach (Sanura, 2023). It incorporates innovative pedagogies such as heutagogy and andragogy, which promote self-directed learning and critical thinking (Blaschake, 2021; Porman Lumban Goal, 2020). Additionally, it extends the concept of learning spaces from outdoor classroom environments to include specialized environments like Makerspaces, STEM Community Hubs, and Virtual Learning Environments, which are designed to foster collaboration and hands-on learning (Bruno Schardong et al., 2020; Hadad, 2020; L. Peterson & Scharber, 2018). The technological component is also significantly advanced, with the inclusion of collaborative technologies, advanced digital tools, and computational thinking, thereby creating a more engaging and interactive learning experience. Overall, the oPSTi framework integrates these enhanced elements to create a holistic, student-centered educational experience that is adaptive to the evolving demands for STEM education among Southeast Asian educators.

Project-Based Learning in STEM Education

The oPSTi framework can be effectively integrated with Project-Based Learning (PBL) to enhance the teaching and learning experience. According to Chistyakov et al (2023), pedagogical strategies through project based learning can influence on student learning, especially in science and STEM education. Project-based learning is a process-oriented learning approach (Mazlini Adnan et al., 2018)that requires flexible learning spaces which is the learning can be everywhere by used of technology tools (Sanura & Rozniza, 2022).

PBL inherently relies on innovative pedagogies (Imms & Kvan, 2021). Therefore, the oPSTi framework emphasizes activities and strategies such as heutagogy and andragogy, which are critical in PBL. According to Mahat and colleagues (2018) these approaches encourage students to take control of their learning process, fostering self-directed learning, which is a core principle of PBL. Project-based learning strategies can upgrade understudies' basic and imaginative reasoning abilities in science acquiring. According to Zulyusri and colleagues (2023), teachers can use the syntax of the project-based learning method to assist students in optimizing their creativity and critical mindsets. By project based learning, students starting learning with essential questions, working together to plan, developing project completion schedules, timelines, and deadlines (Zulyusri et al., 2023).

The framework includes various learning environments like Makerspaces, STEM Community Hubs, Virtual Learning Environments (VLEs), and Outdoor Learning Environments. PBL benefits from these diverse spaces as they provide flexible and dynamic environments where students can collaborate, experiment, and engage in hands-on activities crucial for project-based tasks (Barak, 2020; Nurul Natrah & Ahmad Shidki, 2020; Wang, 2023).

PBL requires the integration of collaborative technologies, digital learning tools, and computational thinking (Malik & Zhu, 2023). The oPSTi framework highlights the use of hardware and software tools, especially the Magnetcode application, screen casting, and other media technologies, which guide teachers to facilitate the implementation of PBL by enabling students to research, collaborate, and present their projects effectively (Khusna et al., 2022; Lin et al., 2021).

The effective implementation of PBL is supported by the oPSTi framework through the creation of conducive learning spaces and the selection of appropriate technological tools. By ensuring that the physical and virtual spaces are suitable for collaborative and interactive learning, the framework enhances the efficacy of PBL. Therefore, both the oPSTi framework and PBL focus on clear learning objectives. For instance, applying technical skills and engaging in collaborative projects help achieve specific learning outcomes. Teachers using the oPSTi framework are guided to set objectives that align with the goals of PBL, ensuring that students develop critical thinking, problem-solving, and teamwork skills.

Methodology

This study used a quantitative approach with a case study design. The researcher employed a one-group post-test design and to evaluate the effectiveness of the oPSTi framework in enhancing project-based learning among Southeast Asia country STEM secondary school educators. The researcher used purposive sampling to select 22 educators who teach STEM subjects, ensuring the participants are directly involved in the areas most likely to benefit from the integration of project based learning using Magnetcode application. The intervention consists of a workshop focused on the practical application of coding and programming through Magnetcode for STEM-based hands-on projects. To assess the impact of integration oPSTi framework using the Magnetcode application, the researcher measured the effectiveness of the oPSTi application among the educators before and after the workshop using standardized survey questions. Five-point Likert scale was used to gather the mean for the impact of the framework.

The oPSTi framework, as outlined by Sanura (2023), provides a structured approach for teachers to achieve their teaching and learning goals through the integration of various strategies and tools (Peterson et al., 2018). Teachers are encouraged to set clear objectives, such as the application of technical skills using diverse media (Lock et al., 2021). They should plan appropriate strategies within their learning environments, like active learning, which facilitates student engagement through discussion or interactive demonstrations. The creation and selection of effective activities, including online learning, is crucial, as is ensuring that the learning spaces, such as collaborative teaching areas, are suited to these activities (Bojer, 2019; Chiasson, 2022). The framework also emphasizes the importance of selecting appropriate technological tools such as smart phone (Schuck et al., 2017), laptop and screen casting for online tutorials, which allow students to engage and build on prior knowledge through peer discussions (Sage et al., 2020). Implementing the oPSTi framework boosts teachers' confidence in using technology, enabling them to evaluate learners with a scaffolding approach that prioritizes student learning and allows for flexible teaching sessions.

Findings and Discussion

This study investigates the impact of the oPSTi Framework on teaching and learning among Southeast Asia educators. Focusing on what is the impact of the oPSTi framework on teaching and learning, the findings ought to answer the research objective and research question in this study. Table 1.0 shows the quantitative findings from the case study design in implementation of the oPSTi framework. The findings reveal significant improvements in teaching practices, experiences, and confidence levels. The mean values for various aspects of the framework's implementation range from 4.41 to 4.68, indicating a high level of effectiveness and satisfaction among the participants as show in Table 1.

Table 1: The Impacts of the oPSTi Framework

No	Impacts of the oPSTi Framework	N	Mean	Standard Deviation
1	The teaching activities introduced in the workshop using oPSTi Framework enhanced my teaching	22	4.41	.503
2	The pedagogies strategies embedded in the oPSTi Framework enhanced my teaching	22	4.59	.503
3	The teaching activities introduced in the workshop using the oPSTi Framework enhanced my teaching experience.	22	4.59	.503
4	The pedagogies strategies embedded in the oPSTi Framework enhanced my teaching experience.	22	4.55	.510
5	The activities during the workshop using the oPSTi Framework provided effective methods for integrating self-determined learning into my teaching]	22	4.55	.510
6	Adult learning was visible during the activities conducted in the workshop using the oPSTi Framework	22	4.45	.596
7	Activities conducted in the makerspace during the workshop using the oPSTi Framework was beneficial for my understanding.	22	4.50	.598
8	The tools utilized in the Makerspace using the oPSTi Framework enhanced my teaching and learning.]	22	4.41	.503
9	The Virtual Learning Environment (VLE) simulation in the workshop using the oPSTi Framework was effective in demonstrating the integration of Magnetcode	22	4.68	.477
10	Project based learning applied in the workshop using the oPSTi Framework contributed to my understanding of integrating Magnetcode	22	4.68	.477
11	The technology tools (hardware) used in the workshop using the oPSTi Framework were effective for integrating Magnetcode in my teaching.	22	4.55	.510
12	The technology tools (software) introduced in the workshop using the oPSTi Framework were helpful in understanding the integration of Magnetcode in the project	22	4.68	.477
13	The digital learning tools used in the workshop using the oPSTi Framework will be beneficial for integrating Magnetcode in my teaching practices.]	22	4.50	.512
14	The workshop using the oPSTi Framework enhanced my skills in computational thinking and coding with Magnetcode	22	4.64	.492
15	I feel more confident to use the oPSTi Framework in my educational practices after attending the workshop.]	22	4.50	.673
16	I will recommend this workshop to other educators to integrate the oPSTi Framework elements into their teaching and learning practices.]	22	4.64	.492
17	The elements in the oPSTi Framework increase my motivation to teach.	22	4.55	.739
18	Overall, the workshop using the oPSTi Framework significantly encouraged me to transform my teaching strategies.	22	4.64	.492

Table 1 illustrated the integration of the oPSTi Framework in teaching activities resulted in enhanced teaching practices and experiences, with mean values of 4.41 and 4.59 respectively. Educators reported that the pedagogical strategies embedded in the framework were particularly effective, with a mean value of 4.55 for enhancing teaching experiences. This demonstrates that the framework successfully incorporates innovative teaching methods that resonate well with educators.

The study also found that the activities conducted during the workshop provided effective methods for integrating self-determined learning into teaching practices, with a mean value of 4.55. Additionally, the visibility of adult learning principles during these activities received a mean score of 4.45, indicating that the framework aligns well with adult learning theories, making it suitable for professional development. The use of the makerspace and technology tools such as Magnetcode application within the oPSTi Framework was highly beneficial.

Educators found the tools used in the makerspace (mean value 4.50) and the integration of Magnetcode in the Virtual Learning Environment (VLE) simulation (mean value 4.68) to be particularly effective. This highlights the importance of practical, hands-on learning environments and advanced technology tools in enhancing teaching practices.

Project-based learning, as applied in the workshop, contributed significantly to the understanding and integration of Magnetcode, with mean values of 4.68 for both software and hardware tools. The framework also enhanced educators' skills in computational thinking and coding, reflected in a mean value of 4.64. This underscores the framework's effectiveness in promoting critical STEM skills. The workshop using the oPSTi Framework significantly boosted educators' confidence in their teaching practices, with a mean value of 4.50, and increased their motivation to teach, with a mean value of 4.55. The willingness to recommend the workshop to peers (mean value 4.64) indicates a strong endorsement of the framework's benefits.

Conclusion

The study underscores the transformative impact of the oPSTi Framework on teaching and learning in Southeast Asia. The framework's emphasis on integrating pedagogy, learning spaces, and technology has proven to be highly effective in enhancing teaching practices, educator experiences, and confidence levels. The findings suggest that the oPSTi Framework's approach to self-determined learning, adult learning principles, and project-based learning is particularly beneficial in fostering a dynamic and effective teaching environment.

References

Adnan, M., Puteh, M., Tajuddin, N. M., Maat, S. M., & Hoe, N. C. (2018). Integrating STEM Education through Project-Based Inquiry Learning in Topic Space Among Year One Children. *The Turkish Online Journal of Design*, Art and Communication-TOJDAC, 1383–1390. https://doi.org/10.7456/1080SSE/185

Barak, M. (2020). Problem-, Project- and Design-Based Learning: Their Relationship to Teaching Science, Technology and Engineering in School. *Journal of Problem-Based Learning, 7*(2), 94–97. https://doi.org/10.24313/jpbl.2020.00227

Blackley, S., & Howell, J. (2019). The next chapter in the STEM education narrative: Using robotics to support programming and coding. *Australian Journal of Teacher Education, 44*(4). https://doi.org/10.14221/ajte.2018v44n4.4

Blaschake, L. (2021). Heutagogy: The pedagogy of agency. *Pacific Journal of Technology Enhanced Learning, 3*(1). https://doi.org/10.24135/pjtel.v3i1.110

Bojer, B. (2019). Unlocking Learning Spaces-An Examination of the Relationship between the Design of Learning Spaces and Pedagogical Practices (Issue December 2019) [Rune Fjord Studio & The Royal Danish Academy of Fine Arts.]. https://doi.org/10.13140/RG.2.2.30247.70562/1

Cerstin, M., & Andreas, H. (2019). Digital Transformation in Higher Education—Buzzword or Opportunity? ELearn.

Chiasson, M. (2022). The Relationship Between Learning Spaces and the Development of Computational Thinking Skill. *Annual Meeting of the American Educational Research, 1*–21. https://doi.org/10.3102/1440741

Daugherty Michael K., & Carter, V. (2019). STEM Education: The Potential of Technology Education. In The Mississippi Valley Conference in the 21st Century: Fifteen Years of Influence on Thought and Practice (pp. 195–229).

Economic Planning Unit. (2021). Malaysia Digital Economy Blueprint. In Economic Planning Unit Prime Minister'S Department.

Faikhamta, Chatree, Lertdechapat, & Kornkanok. (2020). The Impact of a PCK-based Professional Development Program on Science Teachers' Ability to Teaching STEM. *Journal of Science & Mathematics Education in Southeast Asia, 43*(1).

Fisher, K. (2005). Linking Pedagogy and Space. In Department of Education and Training [Victoria] (Issue March).

García-Peñalvo, F. J., Reimann, D., & Maday, C. (2018). Introducing Coding and Computational Thinking in the Schools: The TACCLE 3 – Coding Project Experience. Computational Thinking in the STEM Disciplines, 213–226.

Hadad, R. (2020). The Use of Makerspaces for the Development of Computational Thinking Skills and Dispositions.

Hidiroğlu, Ç. N., & Karakaş, A. (2022). Transdisciplinary role of technology in STEM education. *Malaysian Online Journal of Educational Technology, 2022*(4), 276–293. https://doi.org/10.52380/mojet.2022.10.4.411

Hsieh, M. C., Pan, H. C., Hsieh, S. W., Hsu, M. J., & Chou, S. W. (2022). Teaching the Concept of Computational Thinking: A STEM-Based Program With Tangible Robots on Project-Based Learning Courses. *Frontiers in Psychology, 12*. https://doi.org/10.3389/fpsyg.2021.828568

Imms, W., & Kvan, T. (2021). Teacher Transition into Innovative Learning Environments. In Teacher Transition into Innovative Learning Environments. Springer. https://doi.org/10.1007/978-981-15-7497-9

Khairani, A. Z. (2017). Assessing Urban and Rural Teachers' Competencies in STEM Integrated Education in Malaysia. MATEC Web of Conference (ENCON), 1–5.

Khusna, N. I., Sumarmi, Bachri, S., Astina, I. K., Nurhayati, D. A. W., & Shresthai, R. P. (2022). New Technologies for Project-Based Empathy Learning in Merdeka Belajar (Freedom to Learn): The Use of inaRISK Application and Biopore Technology. *International Journal of Interactive Mobile Technologies, 16*(22), 94–110. https://doi.org/10.3991/ijim.v16i22.36153

Lakshminarayanan, V., & McBride, A. C. (2015). The use of high technology in STEM education. Education and Training in Optics and Photonics: *ETOP 2015, 9793*, 1–13. https://doi.org/10.1117/12.2223062

Lin, K. Y., Wu, Y. T., Hsu, Y. T., & Williams, P. J. (2021). Effects of infusing the engineering design process into STEM project-based learning to develop preservice technology teachers' engineering design thinking. *International Journal of STEM Education, 8*(1). https://doi.org/10.1186/s40594-020-00258-9

Lock, J., Lakhal, S., Cleveland-Innes, M., Arancibia, P., Dell, D., & De Silva, N. (2021). Creating technology-enabled lifelong learning: A heutagogical approach. *British Journal of Educational Technology, 52*(4). https://doi.org/10.1111/bjet.13122

Malik, K. M., & Zhu, M. (2023). Do project-based learning, hands-on activities, and flipped teaching enhance student's learning of introductory theoretical computing classes? *Education and Information Technologies, 28*(3), 3581–3604. https://doi.org/10.1007/s10639-022-11350-8

Mason, S. L., & Rich, P. J. (2019). Preparing Elementary School Teachers to Teach Computing, Coding, and Computational Thinking. *Contemporary Issues in Technology and Teacher Education, 19*(4), 790–824.

Mattila, V., Gauri, P., Dwivedi, P., & Dadhich, D. (2022). The Fifth Industrial Revolution: Enlightenment of 5ire towards Industry 5.0 5ire (Sustainable Distributed Computing). Article in International Journal of Creative Research Thoughts (IJCRT), Vol.10(8), 1–8. www.ijcrt.org

Nik Hazimin, N. H., & Hazrati, H. (2019). Teacher's Perception on Computational Thinking Concept. International Journal of Academic Research in Business and Social Sciences, 9(11), 1536–1546. https://doi.org/10.6007/ijarbss/v9-i11/6718

Norhaqikah, M. K., & Kamisah, O. (2017). STEM-21CS Module: Fostering 21 st Century Skills through Integrated STEM 1. K-12 STEM Education, Vol.3(3), 225–233.

Nurul Natrah, A., & Ahmad Shidki, M. Y. (2020). Conceptualisation of School Makerspace to Support Constructivism and Project-Based Learning in Public Schools in Malaysia. Journal of Advanced Research in Social and Behavioural Sciences, 21(1), 53–74.

Oblinger, D. (2005). Leading the Transition from Classrooms to Learning Spaces. EDUCAUSE Quarterly, 28(1), 14–18.

Peterson, A., Dumont, H., Lafuente, M., & Law, N. (2018). Understanding innovative pedagogies: Key themes to analyse new approaches to teaching and learning. https://doi.org/10.1787/9f843a6e-en

Peterson, L., & Scharber, C. (2018). Learning About Makerspaces: Professional Development with K-12 Inservice Educators. Journal of Digital Learning in Teacher Education, 34(1), 43–52. https://doi.org/10.1080/21532974.2017.1387833

Porman Lumban Goal. (2020). Transformasi Metode Pembelajaran Pasca Pandemi dari Pedagogi, Andragogi ke Heutagogi. Prosiding Konferensi Nasional Ilmu Administrasi 4.0, 1–6.

Qismullah, Y., & Yunisrina, Q. Y. (2018). Digital Culture and Digitagogy: A Life of a Digital Culturalist and a Digitagogist. Proceeding of the International Conference on the Roles of Parents in Shaping Children's Characters (ICECED), 7–14.

Radcliffe, D., Wilson, H., Powell, D., & Tibbetts, B. (2008a). Designing next generation places of learning: Collaboration at the pedagogy-space-technology nexus. The University of Queensland, 1–20.

Radcliffe, D., Wilson, H., Powell, D., & Tibbetts, B. (2008b). Learning Spaces in Higher Education: Positive Outcomes by Design. Proceedings of the Next Generation Learning Spaces 2008 Colloquium, 1–144.

Sage, K., Piazzini, M., Downey, J. C., & Ewing, S. (2020). Flip It or Click It: Equivalent Learning of Vocabulary From Paper, Laptop, and Smartphone Flashcards. Journal of Educational Technology Systems, 49(2), 145–169. https://doi.org/10.1177/0047239520943647

Sanura, J. (2023). Development of Next Generation Learning Spaces (NGLS) Framework in Teachers' Pedagogy and Technology Tools.

Sanura, J., & Rozniza, Z. (2022). Emerging Trends in STEM Education: Envisioning Future Learning Spaces and Interaction Technology Tools Framework using the Fuzzy Delphi Method (FDM). Malaysian International Journal of Research in Teacher Education (MIJORiTE), Vol.3, 45–56.

Sanura, J., Rozniza, Z., & Muhammad Nidzam, Y. (2022). Development of Technology Tools in Next Generation Learning Spaces (Ngls) Framework: a Fuzzy Delphi Analysis. International Journal of Special Education, Special Issue on World of Education and Rehabilitation, Vol.37(3s), 316–331.

Sastra, F., Jilp, J., Nani Prihatmi, T., Istiqoma, M., Anjarwati, R., & Author, C. (2021). ASSURE Model for Teaching Speaking Online: Teacher Self Reflections. Jurnal Ilmiah Langue and Parole, 4(2). http://e-journal.sastra-unes.com/index.php/JILP

Schardong, B., Vindigni, M., & Lee, S. (2020). Developing Makerspace For Wahaha International School.

Schuck, S., Kearney, M., & Burden, K. (2017). Exploring mobile learning in the Third Space. Technology, Pedagogy and Education, 26(2), 121–137. https://doi.org/10.1080/1475939X.2016.1230555

Siti Noor Aneeis, H., Razifah, O., Jashira, J., Amirah, A. H., Vejaratnam, N., Hamdan, I., Semin, M., Izzat Fadhli, H., & Juritah, M. (2022). Barriers to online teaching and learning in computer science. Journal of Positive School Psychology, vol.6(4), 1802–1809. http://journalppw.com

Stamatios, P., Michail, K., & Ali Ibrahim, C. G. (2023). STEM, STEAM, Computational Thinking And Coding: Evidence-Based Research And Practice In Children's Development (S. Papadakis, M. Kalogiannakis, & A. I. C. Gözüm, Eds.). Frontiers Media SA. https://doi.org/10.3389/978-2-83251-168-8

Suryani, K., Khairudin, K., Rahmadani, A. F., Widyastuti, R., & Winsa, L. (2024). Implementation of STEM-Oriented MEA learning model to improve computational thinking skills of learners. *Journal of Science and Education (JSE), 4*(2), 125–135. https://doi.org/10.56003/jse.v4i2.289

Susilo, H., & Sudrajat, A. K. (2020). STEM Learning and its Barrier in Schools: The Case of Biology Teachers in Malang City. *Journal of Physics: Conference Series, 1563*(1). https://doi.org/10.1088/1742-6596/1563/1/012042

Wang, Y. (2023). The role of computer supported project-based learning in students' computational thinking and engagement in robotics courses. Thinking Skills and Creativity, 48. https://doi.org/10.1016/j.tsc.2023.101269

Wu, Y.-T., & Anderson, O. R. (2015). Technology-enhanced stem (science, technology, engineering, and mathematics) education. *Journal of Computers in Education, 2*(3). https://doi.org/10.1007/s40692-015-0041-2

Yean, A. S., & Abdul Rahim, S. S. (2021). Greening STEM: A Theoretical Exploration for the Malaysian Context. *Journal of International and Comparative Education, 10*(1), 19–32. https://doi.org/10.14425/jice.2021.10.1.1205

Yeh, C. Y., & Tsai, C. C. (2022). Massive Distance Education: Barriers and Challenges in Shifting to a Complete Online Learning Environment. Frontiers in Psychology, 13, 1–8. https://doi.org/10.3389/fpsyg.2022.928717

Zulyusri, Elfira, I., Lufri, L., & Santosa, T. A. (2023). Literature Study: Utilization of the PjBL Model in Science Education to Improve Creativity and Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA, 9*(1), 133–143. https://doi.org/10.29303/jppipa.v9i1.2555