JPPIPA 10(3) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Exploring Student Technology and Engineering Literacy in Science Learning: an Overview of the Initial Study

Defrizal Hamka[1*], Riandi[2], Irma Rahma Suwarma[3]

[1] Science Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No 229 Bandung, West Java 40154, Indonesia
[2] Science Education, Universitas Muhammadiyah Riau, Jl. Tuanku Tambusai, Pekanbaru, Riau 28290, Indonesia
[3] Department of Physics Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No. 229 Bandung, West Java 40154, Indonesia

Received: January 7, 2024
Revised: February 10, 2024
Accepted: March 25, 2024
Published: March 31, 2024

Corresponding Author:
Defrizal Hamka:
defrizalhamka@upi.edu
defrizalhamka@umri.ac.id

DOI: 10.29303/jppipa.v10i3.6872

Abstract: Technological and engineering literacy is a capability that must be imparted to students in order to be able to compete globally and be able to solve 21st century problems. This study aims to describe aspects of technological and technical literacy of junior high school students. This type of research is descriptive quantitative analysis. Data were obtained from technological and technical literacy test instruments. The test instrument is adopted from tests issued by NAEP. Data were analyzed quantitatively. The research results show that 69.2% in the complete category, 15.4% in the Partial category and incomplete in the Understanding of Technology Principles aspect. The aspect of Developing Solutions and Achieving Goals as many as 54.8% of students fall into the complete category, 19.2% in the Satisfactory category, 15.4% the Essential category, 7.7% the Partial category, and 26.9% incomplete category. Meanwhile, the Communication and Collaboration aspect, 65.4% were in the complete category, and 34.6% were in the incomplete category. three types of assessment targets in the three main TEL assessment areas, with the most complete category being Gather and Organize data and information, followed by Identification of examples of systems or processes and Representation of alternative analysis and solutions. Science learning involving real experiences and design and engineering processes related to technological principles will make students technologically and engineering literate and can improve students' critical thinking and problem solving abilities.

Keywords: Technology and Engineering Literacy; 21st century Skills; Science Learning

Introduction

In an increasingly interconnected and technology-driven world, the ability to understand, navigate, and harness the power of technology and engineering is paramount (Beogard, 2021; Teo, 2019; Pellegrino & Hilton, 2013; Han et al., 2015). In this way, understudies must fulfill the Another level of instruction to compete viably inside the work grandstand, where technological knowledge and skills are dynamically underlined (Avsec & Jamšek, 2018). Understanding and mastery of technology plays an important role in various aspects of life, including in the field of education (Avsec & Jamšek, 2016; Ahmad & Wibawa, 2021). One of the abilities that must be possessed and mastered is technological and engineering literacy (Julia & Isrokatun, 2019). Technological and engineering literacy is a capability that must be imparted to students in order to be able to compete globally and be able to solve 21st century problems. Technological and engineering literacy, or TEL, is not just a skillset but a fundamental literacy that empowers individuals to understand, analyze, and actively engage with the ever-evolving technological landscape.

In this age of rapid innovation, TEL equips us with the knowledge and proficiency to make informed decisions, solve complex problems, and contribute to the development of cutting-edge solutions. Whether it's understanding the principles behind a smartphone, designing sustainable infrastructure, or using artificial

How to Cite:
Hamka, D., Riandi, & Suwarma, I. R. (2024). Exploring Student Technology and Engineering Literacy in Science Learning: an Overview of the Initial Study. *Jurnal Penelitian Pendidikan IPA*, *10*(3), 1188–1194. https://doi.org/10.29303/jppipa.v10i3.6872

intelligence for business optimization, technological and engineering literacy opens doors to endless possibilities (Williams & Beam, 2019; Buckler et al., 2018; K. Y. Lin et al., 2021).

Science education today goes beyond the confines of textbooks and classrooms. It's about equipping students with the tools to understand and engage with the real-world applications of science and technology. One crucial aspect of this modern approach to science education is fostering technological and engineering literacy, or TEL. Today's students are required to be able to identify any gaps in their technology literacy (Julia & Isrokatun, 2019; Techataweewan & Prasertsin, 2018). Engineering-centered literacy and academic discussions are effective methods for expanding meaningful learning in engineering practice (Aguirre-Muñoz & Pantoya, 2016).

Technology and engineering literacy have been renewed since 2010 when the International Technology Education Association (ITEA) was changed to the International Technology & Engineering Educators Association (ITEEA), this demonstrates just how creatively advanced the TEL grading system must be. In 2014, NAEP developed a framework to measure technology and engineering literacy through the National Assessment Governing Board. The focus on TEL started to determine whether they had literacy and to impose whether they had literacy by linking engineering literacy and technology literacy, which had previously been autonomous (ITEEA, 2020; National Assessment Governing Board, 2018; Shakrani, S. M., & Pearson, 2012). Tel is the ability to develop problem-solving solutions, understand the technology principles and strategies necessary to achieve goals, and use, understand and evaluate technologies (Nation Assessment Govering Board, 2018).

The National Assessment of Educational Progress (NAEP), a congressionally mandated project run by the National Center for Education Statistics (NCES) inside the Department of Education and Science Institute (IES), includes the TEL assessment in the United States. There are several initial goals for carrying out TEL evaluations. Although the world of technology is currently experiencing rapid growth and has long been taught in seminaries, it was impossible to determine the precise level of awareness among academics regarding the efficient use and comprehension of technology. In this setting, the assessment was started with the intention of evaluating the significance of TEL scholars (Lee, 2021).

Despite the fact that technology and engineering are very different from each other, they are closely related, so it is important to train students (Techakosit & Nilsook, 2018; Miska et al., 2022). Some research results found that even while technology is available in particular at universities that train teachers, there is still a paucity of instruction in learning (Voogt & McKenney, 2017; Fraile et al., 2018; Ceha et al., 2016). Technology can also be a solution to train critical thinking skills, creative thinking, collaboration, communication and several other skills (Sriyanto, 2021). Critical thinking abilities can be enhanced by incorporating engineering concepts into approaches to science, technology, engineering, and mathematics (Sulistiowati et al., 2019). As thus, scientific, mathematical, and linguistic literacy share many similarities with technology and engineering literacy. Similar to these other types of academic literacy, technology and engineering literacy entails mastering a set of skills required to contribute meaningfully and wisely to society. Although the means are different, the end result is the same.

Technological and engineering literacy in science learning is about preparing the next generation to be scientifically savvy and technologically adept problem solvers. It encourages students to explore not just the "what" and "why" of scientific phenomena but also the "how" and "what if." It's an educational journey that immerses learners in the intersection of science, technology, and engineering, where they can investigate, design, and innovate (Sommer & Ritzhaupt, 2018; National Assessment Governing Board, 2012).

As students embark on this journey, they'll find themselves unraveling the mysteries of the natural world while gaining the skills to create and enhance it. TEL emphasizes the practical applications of scientific knowledge, promoting hands-on experimentation, and encouraging students to think like engineers and technologists (Anjarsari et al., 2020)

This introduction sets the stage for an exciting exploration of technological and engineering literacy in science learning. Together, we'll discover how TEL bridges the gap between theory and practice, empowering students to become informed, inquisitive, and innovative contributors to the scientific and technological advancements that shape our future.

Students' initial knowledge of technological and engineering literacy is needed to deepen the research base in order to develop learning models that can serve the development of students' engineering and technological knowledge. This research aims to describe a tool for testing students' technological and engineering knowledge and initial understanding of technology and engineering.

Method

This study is a descriptive quantitative study. The testing tool measuring students' technology and engineering knowledge has been adapted to the dimensions and indicators included in the 2018 National Assessment of Educational Progress (NAEP) (Nation Assessment Govering Board, 2018). This test tool is given to 8th grade Junior high school students at Pekanbaru. The populations were all Class VIII students of Junior high school students at Pekanbaru, with 31 students as sample taken using random sampling technique. The test instrument has been adjusted to technology and engineering literacy indicator. Data was also collected through interviews with students to explore in-depth information regarding the teacher's learning process. The NAEP test topic used is the Chicago water problem. The data was obtained from a tool that tests technology and engineering knowledge. The data obtained were analyzed descriptively.

The aspects which are measured are understanding technological principle, developing solutions and achieve goals and communicating and collaborating. Understanding technological principle expects students have ability to explain features and processes of a system (technology) and make a prediction, comparison, and evaluation of a technology. Developing solutions and achieve goals expects students to use knowledge on technology, device and skill to solve a device issue, implement knowledge possessed to solve, design and make a product through an appropriate process and by using relevant device. Communicating and collaborating are focused students will be expected to be fluent in the use of information and communication technologies. Technology literacy scores are informed in the form of complete, satisfactory, essential, partial and unsatisfactory / incomplete criteria. In order to obtain students' technology and engineering literacy data, scoring towards students'answer from 6 questions is measured. technological and engineering literacy criteria for each student are categorized.

Result and Discussion

This research is a preliminary study conducted to determine the initial technological and engineering literacy abilities of junior high school students. The method used in this research is a descriptive analysis method to describe a phenomenon that exists at the research location in a systematic, realistic, accurate and original manner. Information that is considered important is collected as a basis for developing further research. The Technology and Engineering Knowledge Checker is designed to absorb students' initial knowledge of technology and engineering.

There are three aspects of technology and engineering literacy which is measured in this research. First, aspect of understanding technological principles which focuses on knowledge and understanding of students on technology and their ability to think and reason by using the technology knowledge. Second, aspect of developing solution and achieve goals are focused on the implementation of knowledge of technology, device and skill of students to solve a problem and reach the goal as presented in the social, curriculum, design, and realistic context and aspect of communicating and collaborating are focused students will be expected to be fluent in the use of information and communication technologies. Referring to the technology and engineering literacy test framework developed by NAEP 2018, on the topic of the Chicago water problem, with a content area consisting of: technology and society, design and systems, and a practice area consisting of: understanding technological principles, developing solutions and achieving goals, communicating and collaborating. The technology and engineering literacy test consists of six questions, with each question having a different scoring guide. The first question consists of three scores (Complete, Partial, Incomplete), the second question (Complete, Essential, Partial, Incomplete), the third question (Complete, Satisfactory, Essential, Partial, Incomplete), the fourth question (Complete, Partial, Incomplete), fifth question (Complete, Incomplete), and sixth question (Complete, Incomplete). The conditions/descriptions for each score are as follows: 1) complete, that is if the answer or all answer choices are answered correctly, 2) satisfactory, that is if one of the total answer choices is wrong, 3) essential, that is if two of the total answer choices incorrect, 4) partial, namely if only one of the answer choices is correct, and 5) incomplete, namely if there is no correct answer. Third aspects are divided into six indicators which refer to NAEP TEL 2018, which identify examples of a system or process, select appropriate technology to solve a societal problem, develop a plan to investigate an issue, gather and organize data and information, analyze and compare advantages and disadvantages of a proposed solution and represent alternative analyses and solutions.

Based on the table 2 the percentage of technology and engineering literacy of students for each Aspect, it is known that for understanding technological principles 69.2% students are in complete category, 15.4% in partial and incomplete category, for developing solutions and achieving goals 54.8% in complete category, 19.2% in satisfactory category, 15.5% in essential category, 7.7% in partial category, 26.9% in incomplete category, and for communicating and collaboratingthe 65.4% in complete category and 34.6% in incomplete category.

Table 1. The percentage of technology and engineering literacy of students for each Aspect

Aspect of Technology and Engineering Literacy	Score	Percentage
Understanding Technological Principles	Complete	69.2
	Partial	15.4
	Unsatisfactory / Incomplete	15.4
Developing Solutions and Achieving Goals	Complete	54.8
	Satisfactory	19.2
	Essential	15.4
	Partial	7.7
	Unsatisfactory / Incomplete	26.9
Communicating and collaborating	Complete	65.4
	Unsatisfactory / Incomplete	34.6

Based on the table 3 the percentage of technology and engineering literacy of students for each indicator, it is known that for identify examples of a system or process 69.2 % students are in complete category, 15.4% in partial and incomplete category, for select appropriate technology to solve a societal problem 53.8 % in complete category, 30.8 % in essential category, 7.7 % in partial category, 7.7 % in incomplete category, for develop a plan to investigate an issue 42.3 % in complete category, in Satisfactory category, 19.2 %, in partial category, 15.4 % and 23.1 % in incomplete category. For gather and organize data and information 76.9 % in complete category, 23.1 % in incomplete category, for analyze and compare advantages and disadvantages of a proposed solution 46.2 % in complete category, 53.8 % in incomplete category. For represent alternative analyses and solutions 65.4 % in complete category, 34.6 % in incomplete category.

The results of the research show that although the majority of students' technological and technical literacy are in the complete category, there are still students in the incomplete category. For example, in the aspect of communication and collaboration, the percentage of incomplete scores is quite large, this could happen because students are not used to being trained in these abilities and skills. Likewise with the Developing Solutions and Achieving Goals aspects. Thus, technological and engineering literacy skills should be a priority for students to train. The results of the research show that although the majority of students' technological and technical literacy are in the complete category, there are still students in the incomplete category. For example, in the indicator of analyze and compare advantages and disadvantages of a proposed solution, the percentage of incomplete scores is quite large, this could happen because students are not used to being trained in these abilities and skills. These results are supported by conducting interviews with students regarding how the learning process has been carried out so far by teachers, most of them answered that learning is still dominated in the form of presentations using power points and using existing textbooks. In the future, students should be trained more often to compare the advantages and disadvantages of the solutions they are trying to propose through more directed studies. Actions that can be taken by continuously training students in the use of technology so that this becomes a habit (López-Meneses et al., 2020).

Tabel 2. The percentage of technology and engineering literacy of students for each indicator

Types of assessment targets	Score	Percentage
Identify examples of a system or process	Complete	69.2
	Partial	15.4
	Unsatisfactory / Incomplete	15.4
Select appropriate technology to solve a societal problem	Complete	53.8
	Essential	30.8
	Partial	7.7
	Unsatisfactory / Incomplete	7.7
Develop a plan to investigate an issue	Complete	42.3
	Satisfactory	19.2
	Essential	0.0
	Partial	15.4
	Unsatisfactory / Incomplete	23.1
Gather and Organize data and information	Complete	76.9
	Partial	0.0
	Unsatisfactory / Incomplete	23.1
Analyze and Compare advantages and disadvantages of a proposed solution	Complete	46.2
	Unsatisfactory / Incomplete	53.8
Represent alternative analyses and solutions	Complete	65.4
	Unsatisfactory / Incomplete	34.6

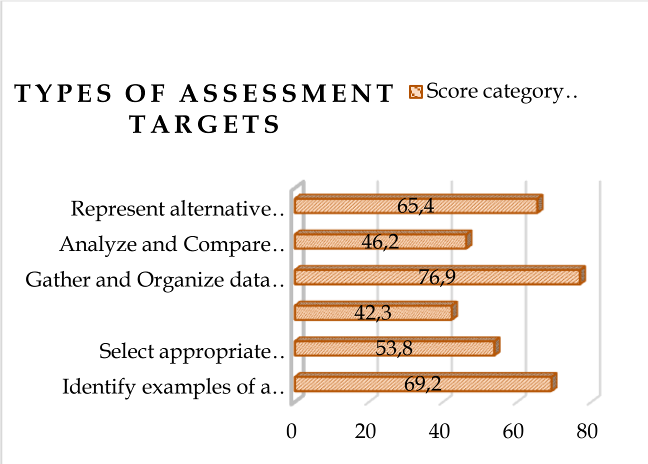

Figure 1. Achievement Type of assessment target in the complete category score

The effort to increase technology and engineering literacy is required. A correct learning method can influence technology and engineering literacy of students. The research Firman et al. (2016), Anjarsari et al. (2020), Apriyani et al. (2019), Pramasdyahsari et al. (2023), indicates that natural science learning which is based on Science, Technology, Engineering, and Mathematics positively affect STEM literacy and technology and engineering literacy of students. This means that appropriate learning approaches and models, for example, STEM, can be used in the learning process (Jackson et al., 2021; Shukshina et al., 2021). It means that by integrating the four knowledge, technology and engineering literacy of students will be increased. A learning which involves design and technique process should be attuned to improve students' critical thinking, creative thinking and problemsolving skills (Ridlo, 2020; Purwaningsih et al., 2020; Sumarni & Kadarwati, 2020; Nugroho et al., 2019). Besides, natural science learning by involving real experience on principles of technology will make students to literate in technology and engineering. According to Anjarsari et al. (2020), Firman et al. (2016), Long et al. (2020), Usnia et al. (2021), C. L. Lin & Chiang, (2019), Simarro & Couso (2021), K. Y. Lin et al. (2020), natural science learning uses engineering design process and STEM-PjBL approach that gives students a knowledge on science and real world. Through this learning, students can practice knowledge and technology in solving daily life problem.

Conclusion

Included in complete category, but there are also incomplete ones. Besides, technology and engineering literacy of students for each indicator are divided into complete category. Likewise, there are also incomplete ones. These results also show a functional relationship between enjoying learning activities and motivation to participate in discussions. Overall, engineering-centered literature and academic discussions are effective methods for extending meaningful learning in engineering practice. The increase of technology and engineering literacy can be done by using a learning method that involves science and principles of technology and engineering. Science learning involving real experiences and design and engineering processes related to technological principles will make students technologically and engineering literate and can improve students' critical thinking and problem solving abilities.

Acknowledgments

The researcher would like to thank the supervisors at the Faculty of Mathematics and Natural Sciences Education, Universitas Pendidikan Indonesian, the principals, teachers and students of Pekanbaru City who have assisted in carrying out this research.

Author Contributions

Defrizal Hamka: writing-original draft preparation, result, discussion, methodology, conclusion, and editing; Riandi and Irma Rahma Suwarna: analysis, review, and proofreading.

Funding

Researchers independently funded this research.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

Aguirre-Muñoz, Z., & Pantoya, M. L. (2016). Engineering Literacy and Engagement in Kindergarten Classrooms. *Journal of Engineering Education*, *105*(4), 630–654. https://doi.org/10.1002/jee.20151

Ahmad, J., & Wibawa, F. A. (2021). Peran Literasi Teknologi Dalam Pembelajaran Daring. *Jurnal Lentera Pendidikan Pusat Penelitian Lppm Um Metro*, *6*(2), 237–243. Retrieved from http://www.ojs.ummetro.ac.id/index.php/lentera/article/view/1820

Anjarsari, P., Prasetyo, Z. K., & Susanti, K. (2020). Developing technology and engineering literacy for Junior High School students through STEM-based science learning. *Journal of Physics: Conference Series*, *1440*(1). https://doi.org/10.1088/1742-6596/1440/1/012107

Apriyani, R., Ramalis, T. R., & Suwarma, I. R. (2019). Analyzing Student's Problem Solving Abilities of

Direct Current Electricity in STEM-based Learning. *Journal of Science Learning*, *2*(3), 85–91. https://doi.org/10.17509/jsl.v2i3.17559

Avsec, S., & Jamšek, J. (2016). Technological literacy for students aged 6–18: a new method for holistic measuring of knowledge, capabilities, critical thinking and decision-making. *International Journal of Technology and Design Education*, *26*(1), 43–60. https://doi.org/10.1007/s10798-015-9299-y

Avsec, S., & Jamšek, J. (2018). A path model of factors affecting secondary school students' technological literacy. *International Journal of Technology and Design Education*, *28*(1), 145–168. https://doi.org/10.1007/s10798-016-9382-z

Beogard, G. (2021). A list of Skills for The 21st Century. *Journal of Educational Studies and Technology*, *45*(2), 45–61.

Buckler, C., Koperski, K., & Loveland, T. (2018). Is computer science compatible with technological literacy? *Technology and Engineering Teacher*, *77*(4), 15–20. Retrieved from https://www.purdue.edu/in-mac/assets/pdf/TET77-4web-2.pdf#page=15

Ceha, R., Prasetyaningsih, E., Bachtiar, I., & Nana S., A. (2016). Peningkatan Kemampuan Guru Dalam Pemanfaatan Teknologi Informasi Pada Kegiatan Pembelajaran. *ETHOS (Jurnal Penelitian Dan Pengabdian)*, 131. https://doi.org/10.29313/ethos.v0i0.1693

Firman, H., Rustaman, N. Y., & Suwarma, I. R. (2016). Development Technology and Engineering Literacy Through STEM-Based Education. In *2015 International Conference on Innovation in Engineering and Vocational Education,* 209–212. https://doi.org/10.2991/icieve-15.2016.45

Fraile, M. N., Peñalva-Vélez, A., & Lacambra, A. M. M. (2018). Development of digital competence in secondary education teachers' training. *Education Sciences*, *8*(3). https://doi.org/10.3390/educsci8030104

Han, S., Capraro, R., & Capraro, M. M. (2015). How Science, Technology, Engineering, and Mathematics (Stem) Project-Based Learning (Pbl) Affects High, Middle, and Low Achievers Differently: the Impact of Student Factors on Achievement. *International Journal of Science and Mathematics Education*, *13*(5), 1089–1113. https://doi.org/10.1007/s10763-014-9526-0

ITEEA. (2020). *Standards for Technological and Engineering Literacy The Role of Technology and Engineering in STEM Education*. Technical Foundation of America and the National Science Foundation. Retrieved from https://www.iteea.org/File.aspx?id=168785&v=fb52b0c8%0Ahttps://www.iteea.org/stel.aspx

Jackson, C., Mohr-Schroeder, M. J., Bush, S. B., Maiorca, C., Roberts, T., Yost, C., & Fowler, A. (2021). Equity-Oriented Conceptual Framework for K-12 STEM literacy. *International Journal of STEM Education*, *8*(1). https://doi.org/10.1186/s40594-021-00294-z

Julia, J., & Isrokatun, I. (2019). Technology literacy and student practice: Lecturing critical evaluation skills. *International Journal of Learning, Teaching and Educational Research*, *18*(9), 114–130. https://doi.org/10.26803/ijlter.18.9.6

Lee, C.-S. (2021). Exploring the Assessment of Technology and Engineering Literacy in the United States. *Journal of Korean Practical Arts Education*, *27*(3), 137–154.

Lin, C. L., & Chiang, J. K. (2019). Using 6E model in STEM teaching activities to improve university students' learning satisfaction: A case of development seniors IoT smart cane creative design. *Journal of Internet Technology*, *20*(7), 2109–2116. https://doi.org/10.3966/160792642019122007009

Lin, K. Y., Hsiao, H. S., Williams, P. J., & Chen, Y. H. (2020). Effects of 6E-oriented STEM practical activities in cultivating middle school students' attitudes toward technology and technological inquiry ability. *Research in Science and Technological Education*, *38*(1), 1–18. https://doi.org/10.1080/02635143.2018.1561432

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), 1–15. https://doi.org/10.1186/s40594-020-00258-9

Long, N. T., Yen, N. T. H., & Van Hanh, N. (2020). The role of experiential learning and engineering design process in k-12 stem education. *International Journal of Education and Practice*, *8*(4), 720–732. https://doi.org/10.18488/journal.61.2020.84.720.732

López-Meneses, E., Sirignano, F. M., Vázquez-Cano, E., & Ramírez-Hurtado, J. M. (2020). University students' digital competence in three areas of the DigCom 2.1 model: A comparative study at three European universities. *Australasian Journal of Educational Technology*, *36*(3), 69–88. https://doi.org/10.14742/AJET.5583

Miska, J. W., Mathews, L., Driscoll, J., Hoffenson, S., Crimmins, S., Espera, A., & Pitterson, N. (2022). How do undergraduate engineering students conceptualize product design? An analysis of two third-year design courses. *Journal of Engineering Education*, *111*(3), 616–641. https://doi.org/10.1002/jee.20468

Nation Assessment Govering Board. (2018). *Technology and Engineering Literacy Framework for the 2018 National Assessment of Educational Progress*. The National Academies Press.

National Assessment Governing Board. (2012). *Technological Literacy Assessment and Item Specifications for the 2012 National Assessment of Educational Progress.* Contract.

National Assessment Governing Board. (2018). *Technology and Engineering Literacy Framework for the 2018 National Assessment of Educational Progress*. The National Academies Press.

Nugroho, O. F., Permanasari, A., & Firman, H. (2019). Program Belajar berbasis STEM untuk Pembelajaran IPA: Tinjauan Pustaka, dengan Referensi di Indonesia. *Jurnal Eksakta Pendidikan (Jep)*, *3*(2), 117. https://doi.org/10.24036/jep/vol3-iss2/328

Pellegrino, J. W., & Hilton, M. L. (2013). *Education for life and work: Developing transferable knowledge and skills in the 21st century.* In The National Academies Press. https://doi.org/10.17226/13398

Pramasdyahsari, A. S., Setyawati, R. D., Aini, S. N., Nusuki, U., Arum, J. P., Astutik, I. D., Widodo, W., Zuliah, N., & Salmah, U. (2023). Fostering students' mathematical critical thinking skills on number patterns through digital book STEM PjBL. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(7), em2297. https://doi.org/10.29333/ejmste/13342

Purwaningsih, E., Sari, S. P., Sari, A. M., & ... (2020). The Effect of STEM-PjBL and Discovery Learning on Improving Students' Problem-Solving Skills of Impulse and Momentum Topic. *Jurnal Pendidikan IPA Indonesia, 9*(4), 465-476. Retrieved from https://journal.unnes.ac.id/nju/index.php/jpii/article/view/26432

Ridlo, S. (2020). Critical thinking skills reviewed from communication skills of the primary school students in STEM-based project-based learning model. *Journal of Primary Education, 9*(3), 311-320. Retrieved from https://journal.unnes.ac.id/sju/index.php/jpe/article/view/27573

Shakrani, S. M., & Pearson, G. (2012). *NAEP 2012 technological literacy framework and specifications development: Issues and recommendations*. National Assessment Governing Board.

Shukshina, L. V., Gegel, L. A., Erofeeva, M. A., Levina, I. D., Chugaeva, U. Y., & Nikitin, O. D. (2021). STEM and STEAM Education in Russian Education: Conceptual Framework. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(10), 1–14. https://doi.org/10.29333/ejmste/11184

Simarro, C., & Couso, D. (2021). Engineering practices as a framework for STEM education: a proposal based on epistemic nuances. *International Journal of STEM Education*, *8*(1). https://doi.org/10.1186/s40594-021-00310-2

Sommer, M., & Ritzhaupt, A. (2018). Impact of the flipped classroom on learner achievement and satisfaction in an undergraduate technology literacy course. *Journal of Information Technology Education: Research*, *17*, 159–182. https://doi.org/10.28945/4059

Sriyanto, B. (2021). Meningkatkan Keterampilan 4c dengan Literasi Digital di SMP Negeri 1 Sidoharjo. *Jurnal Didaktika Pendidikan Dasar*, *5*(1), 125–142. https://doi.org/10.26811/didaktika.v5i1.291

Sulistiowati, D., Surtikanti, H. K., & Suwarma, I. R. (2019). Investigating scientific literacy of students on the topic of water pollution through STEM based 6E learning by design. *Journal of Physics: Conference Series*, *1157*(2). https://doi.org/10.1088/1742-6596/1157/2/022038

Sumarni, W., & Kadarwati, S. (2020). Ethno-stem project-based learning: Its impact to critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia, 9*(1), 11-21. Retrieved from https://journal.unnes.ac.id/nju/index.php/jpii/article/view/21754

Techakosit, S., & Nilsook, P. (2018). The development of STEM literacy using the learning process of scientific imagineering through AR. *International Journal of Emerging Technologies in Learning*, *13*(1), 230–238. https://doi.org/10.3991/ijet.v13i01.7664

Techataweewan, W., & Prasertsin, U. (2018). Development of digital literacy indicators for Thai undergraduate students using mixed method research. *Kasetsart Journal of Social Sciences*, *39*(2), 215–221. https://doi.org/10.1016/j.kjss.2017.07.001

Teo, P. (2019). Teaching for the 21st century: A case for dialogic pedagogy. *Learning, Culture and Social Interaction*, *21*, 170–178. https://doi.org/10.1016/j.lcsi.2019.03.009

Usnia, A. M., Prasetyo, Z. K., Wardaya, N. F., & Elviana, R. (2021). A Preliminary Study of Student's Initial Technology and Engineering Literacy. *Proceedings of the 6th International Seminar on Science Education (ISSE 2020)*, *541*, 589–595. https://doi.org/10.2991/assehr.k.210326.085

Voogt, J., & McKenney, S. (2017). TPACK in teacher education: are we preparing teachers to use technology for early literacy? *Technology, Pedagogy and Education*, *26*(1), 69–83. https://doi.org/10.1080/1475939X.2016.1174730

Williams, C., & Beam, S. (2019). Technology and writing: Review of research. *Computers & Education*, *128*, 227–242. https://doi.org/10.1016/j.compedu.2018.09.024