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Research Article

Exploring of Technology and Engineering Literacy (TEL): What, Why, and How

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Abstract.
Challenges in the 21st century that we face as a society certainly need to be handled by young people, in the end giving birth to an idea called Technology and Engineering Literacy (TEL). However, many people do not understand what, why, and how TEL. Therefore, this article discusses issues that are clearly of concern and related to what TEL is, why TEL should exist, and how TEL assessment is implemented in education, especially in science education. This research is included in the parameters of the theme content analysis. This research-based paper uses reflections on literature from various journals, articles, and other textbooks. TEL is the ability to develop solutions to solve problems, understand the principles and technological strategies needed to achieve goals, and use, understand, and evaluate technology. The three areas of TEL that NAEP will evaluate are technology and society, design and systems, and ICT. TEL is very important to be trained and improved in science learning as a provision for students to face 21st century education. The TEL assessment is a computer-based test, the items are composed of scenario-based assessment and discrete item sets, and the data is provided with longitudinal analysis. Implementation of TEL in Science Instruction can be done using learning methods that involve science, technology and engineering principles.

Keywords: Exploring, TEL, What, Why, and How

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1. INTRODUCTION

The use of technology in learning environments is actually necessary for the development of students' literacy abilities in the twenty-first century [1]. Everyone should be knowledgeable about technology to use it effectively [2]. While technology supports effective learning, it is important to learn how to provide effective learning for prospective teachers and teachers in the classroom environment and how to do it [3]. Even though student have been taught about technology and how to utilize different

technological tools for generations, it is impossible to assess the depth of their comprehension of these concepts and their proficiency with technology. Today's students are required to be able to identify any gaps in their technology literacy [4]. Integrating engineering is a means to foster and maintain students' interest in the subject while giving them real-world problem-solving technique [5]. This has been seen, since the release of the Standards for technical Literacy in 2000, an improvement in technical literacy among all pupils has been the primary goal. The objective is to create people who have a comprehensive contextual awareness of technology and its role in society, empowering them to participate actively in the technological world and be responsible makers and consumers of technology [6].

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 [7].

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 [8].

Despite the fact that technology and techniques are very different from each other, they are closely related, so it is important to train students[9][10]. 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 [11]. Critical thinking abilities can be enhanced by incorporating engineering concepts into approaches to science, technology, engineering, and mathematics [12]. 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.

With the current conditions and skill needs, TEL is an important part to be developed and developed for students, however, the fact is that TEL has not been widely used in Indonesian education, especially in terms of teaching science. Therefore, the purpose of this study is to explain in detail about TEL, there are 3 aspects that will be discussed in this study, the first relates to what is Technological and Technical Literacy (TEL). The second, why TEL is important and the third is how TEL is used, this relates to implement and description assessment Technology and engineering literacy (TEL)can be used in learning

2. RESEARCH METHOD

This research is a type of the content analysis study. The chosen data and information were received from literature reviews from various journals, articles, prosiding and textbooks related to Technology and engineering literacy. Initial search identified potential publications in the two selected databases (Eric and Scopus). After analyzing all the articles according to the criteria, 20 articles were finally selected for analysis technology and literacy engineering. The analysis was carried out on the information and data obtained from these various sources. The research questions in this analysis include: the definition of TEL, the importance of TEL, and how to implement TEL. The parameter is the content of the article or theme under this study can be seen in the following Table 1.

Table 1: Example of data analysis.

Parameter	Description
Defenition of Technology and engineering literacy (TEL)	To determine whether definitions are discussed in TEL-related books or articles
The Importance assessment of Technology and engineering literacy (TEL)	To know why it's crucial to perform the TEL assessment
How to implement and description assessment Technology and engineering literacy (TEL)	To see how implement the assessment process TEL

3. RESULT AND DISCUSSION

The present study aims to discuss in depth about what TEL is, why it should be implemented, how to implement and deskription assessment Technology and engineering literacy (TEL), and what efforts can be made by the authorities in the successful implementation assessment of TEL.

3.1. Definition of Technology and Engineering Literacy

Any alteration of the natural world made to satisfy human needs or desires is referred to as technology [10]. Technology literacy as awareness and knowledge of technological tools and purposes paired with practical, professional application skills [4]. Engineering is a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants [7] [13]. Literacy is a fluid construct, meaning that knowledge, skill, and abilities in given field will change over time [6]. Then, 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. the framework for evaluating tels consists of three areas for purpose: technology and society, design and system, and information and communication technologies.

The first, technology and society, involves the effects that technology has on society and on the natural world and the ethical questions that arise from those effects. the second content area, design and systems, covers the nature of technology, the engineering design process by which technologies are developed, and basic principles of dealing with everyday technologies such as maintenance and troubleshooting. the final content area, information and communication technology, includes computers and software learning tools; networking systems and protocols; handheld digital devices; and other technologies for accessing, creating, and communicating information and for facilitating creative expression.

In all three areas of technology and engineering literacy, students are expected to be able to apply specific ways of thinking and reasoning when solving problems. These ideas and reasonings are called “practice” [14]. The framework specifies three types of her practices expected of students, as shown in Table 3. Practice in TEL is used within and across three main evaluation domains, and can be categorized into three broad categories. First, students understand the principles of technology. This includes understanding the nature of technology, knowing its suitability for various digital tools and tasks, and knowing how technology emerges, how it shapes society, and so on.

Table 2: Content areas and subareas TEL.

Technology and Society	Interaction of Technology and Humans
	Effects of Technology on the Natural World
	Effects of Technology on the World of Information and Knowledge
	Ethics, Equity, and Responsibility
Design and Systems	Nature of Technology
	Engineering Design
	Systems Thinking
	Maintenance and Troubleshooting
Information and Communication Technology (ICT)	Construction and Exchange of Ideas and Solutions
	Information Research
	Investigation of Problems
	Acknowledgment of Ideas and Information
	Selection and Use of Digital Tools

Source: National Assessment Governing Board & U.S. Department of Education (2018)

Second, students create problem-solving solutions and achieve goals. These include the proper use of a wide range of technology tools and systems in real life, the knowledge of technology concepts, including engineering design and information technology, and the creative application of technology to solve problems and achieve goals. Third, students communicate and collaborate. In this regard, it is evaluated whether various media are used to effectively convey information and ideas, and whether they collaborate with colleagues and expert [15].

Table 3: Classification of types of assessment targets in the three major assessment areas according to the practices for TEL (example: understanding technological principles).

	Technology and society	**Design and system**	**Information and communication technologies (ICT)**
Understanding Technological principles	**Analyze** advantages and disadvantages of an existing technology **Explain** costs and benefits **Compare** effects of two technolo gies on individuals **Propose** solutions and alternatives **Predict** consequences of a technology **Select** among alternatives	**Describe** features of a system or process **Identify** examples of a system or process **Explain** the properties of different materials that determine which is suitable to use for a given application or product **Analyze** a need **Classify** the elements of a system	**Describe** features and functions of ICT tools **Explain** how parts of a whole interact **Analyze** and compare relevant features **Critique** a process or outcome **Evaluate** examples of effective resolution of opposing points of view **Justify** tool choice for a given purpose

Source: National Assessment Governing Board & U.S. Department of Education (2018)

Table 3 provides typical examples of how these three practices can be used to classify targets in the three main study areas. These are sample ideas for items and assignments and will not be used in the actual assessment. It should be noted again that the boundaries between the practices are not entirely different, but referring to these three practices can assist in the development of tasks and items and the interpretation of student performance for various cognitive demands.

3.2. The Importance of Assessment Technology and Engineering Literacy

Science and technology have a significant impact on contemporary civilization. Everyone has access to a variety of smart devices and cutting-edge applications on a global scale [16][17] [18]. The study of engineering design and systems is about the world in which all human beings live and the world in which students make decisions as workers, consumers, and citizens. 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 [11], teachers in turn need to be literate, to assist students in competency development, and to ensure optimal application of information and communication technology [19][20]. Therefore, when they learn in an isolated and disjointed manner, missing links to cross-cutting topics and real-world applications, students frequently lose interest in science and math [21]. On consideration of issues related to technology and engineering, NAEP-TEL conducted two assessments in 2014 and 2018 with the implications and discussion as follows.

First, NAEP regularly conducts TEL assessments and conducts long-term research on eighth graders. The reasons are technology-related courses, dropout rates, consideration of international academic performance assessments (TIMSS, PISA), and the No Child Left Behind education policy. Second, in create a framework for evaluating TELs, input from numerous professionals and the general public was taken into consideration. Throughout the 15 months of outreach meetings across the nation, thousands of people and organizations with experience in technology education and engineering engaged in the TEL evaluation and gathered feedback from professional groups, practitioners, and members of the general public. 350 responders to online and print surveys offered thorough written input. Future technological literacy evaluations may find practical assistance from these thorough feedback [8]. Third, students' TEL evaluation results are statistically significant in 2018 compared to 2014. The results of the evaluation are analyzed in detail by gender, parent's educational background, school type, and race,

which correspond to independent spokesmen, but only basic variables were presented in this investigation, reflecting the cultural. Fourth, TEL's evaluation results are analyzed into 'technology and society', 'design and systems', and 'ICT', which correspond to the content area. Overall, it has improved significantly in 2018 compared to 2014, continuing to study trends. It was divided into communication and collaborating, developing solutions and achieving governments, and understanding technological principles. There has been a significant improvement in all areas of practice. Fifth, the results of the evaluation of TEL were analyzed and presented by the level of achievement established by NAEP. That is NAEP Basic, NAEP Proficient, and NAEP Advanced, which have significantly increased from 43% to 46%, demonstrating improved levels of achievement. Sixth, as the TEL assessment was conducted periodically, the increase in the number of students taking technology related programs at school had a positive impact on improving their technology and engineering literacy.

In addition, several research results in Indonesia show that most of technology and engineering literacy of students are included in moderate and poor category, which is 62.47% of total sample[22]. Indonesia was ranked 44th out of 47 countries in the 2015 Trends International Mathematics and Science Study (TIMSS) in the category of science [23].

Therefore, based on the considerations above, it is important to evaluate the ability of technological and engineering literacy. The following are things that can be done to carry out the assessment process. [phase I] developed a technological literacy evaluation framework in the Technological Education Society, and [phase 2] was carried out in the regional units that make up the Technological Education Society and the results were announced to establish the context. [Phase ⊠] was partially implemented with support from the provincial education office and positive announcement results. [Phase ⊠] was extended with support from national city and provincial education offices to evaluate and announce positive results to gain context from the public. [Phase 5] will be expanded and implemented nationally and the results will be announced to establish context among the public and implemented periodically.

3.3. How to implement and description assessment Technology and engineering literacy (TEL)

Implementation of TEL in Science Instruction can be done using learning methods that involve science and technology and engineering principles[22]. TEL implementation in

learning can be done in STEM-based science learning, where the results have a positive effect on technological and technical literacy skills among students[24].

An assessment of technological and engineering literacy has been carried out at America through the Nation Governing Board Assessment, while other countries have not yet carried out an assessment. For this reason, it is related to how the implementation of the TEL assessment refers to the TEL assessment process that has been carried out at America. The following describes the process of implementing the TEL assessment process.

3.4. Practices and contexts for technology and engineering literacy

The practices that embody the required thinking and application of students across the three key assessment domains, as well as the knowledge, skill, and evaluation objectives, are critical to understanding in NAEP's TEL assessment. These three factors and relationships are shown in Figure 1. The context of TEL's assessment activities and items includes common problems, issues, and goals that students can encounter in the classroom or in the workplace. The specific knowledge and abilities up for assessment fall into three categories, giving task and question development a structure with evaluation aims, practices, and contexts. The general thinking and reasoning that students are expected to exhibit while responding to assessment assignments and questions is clarified through practice [25].

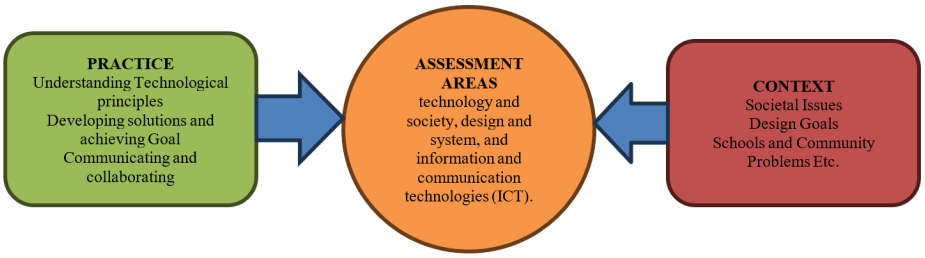

Figure 1: Elements of the NAEP technology and engineering literacy assessment. Source: National Assessment Governing Board & U.S. Department of Education (2014; 2018).

3.5. Overview of the Assessment Design

The three main categories of technology and engineering literacy and the crosscutting practices will be used to identify the tasks and products that make up the domain of technology and engineering literacy achievement. The assessment will be administered by computer and will be composed of sets of long scenarios, short/medium scenarios,

and discrete items. Within each of these types of tasks there will be a variety of selected-response items and short and extended constructed-response items. Student responses will be measured both directly and, in the scenario-based tasks, through their interactions with simulated tools and their manipulation of components of systems.

3.6. Types of Tasks and Items

NAEP created the TEL exam in 2010 as a simulation test, and it has been used as a major test since 2014. To report student accomplishment at the group level, this evaluation is carried out through sampling at the national level. However, it is not intended to assess each student's or school's performance individually. The TEL assessment for the NAEP takes around 60 minutes to complete, plus extra time for the survey that goes along with it.

3.7. Scenario-Based Assessment Sets

There are several short, medium, and lengthy scenario-based examinations available. Answering long scenario questions takes around 30 minutes, medium scenario questions take about 20 minutes, and short scenario questions take about 10 minutes. Although both long and short scenarios have some traits, there are variances in the complexity, number of assessment tasks, and number of response items. A short scenario counts between 5 and 10 achievements, whereas a lengthy scenario counts between 10 and 15. Depending on the scenario, different tools are accessible, and the following examples of questions.

Figure 2: Example task for scenario-based evaluation in tel assessment. Source: https://www.nationsreportcard.gov/tel/tasks/iguana/.

4. CONCLUSION

Many professionals and organizations have proposed definitions of TEL, Technology and engineering literacy to quickly incorporate into academic curricula. TEL is the ability to develop solutions to solve problems, understand the principles and technological strategies needed to achieve goals, and use, understand, and evaluate technology. The three areas of TEL that NAEP will evaluate are technology and society, design and systems, and ICT. TEL is very important to be trained and improved in science learning as a provision for students to face 21st century education. The TEL assessment is computer-based test, the items are composed of scenario-based assessment and discrete item sets, and the data is provided with longitudinal analysis. Implementation of TEL in Science Instruction can be done using learning methods that involve science and technology and engineering principles.

References

[1] Williams C, Beam S. Technology and writing: review of research. Comput Educ. 2019;128:227–42.

[2] Techataweewan W, Prasertsin U. Development of digital literacy indicators for Thai undergraduate students using mixed method research. Kasetsart J Soc Sci. 2018;39(2):215–21.

[3] Yildiz Durak H. Modeling of relations between K-12 teachers' TPACK levels and their technology integration self-efficacy, technology literacy levels, attitudes toward technology and usage objectives of social networks. Interact Learn Environ. 2021;29(7):1136–62.

[4] Julia J, Isrokatun I. Technology literacy and student practice: lecturing critical evaluation skills. International Journal of Learning, Teaching and Educational Research. 2019;18(9):114–30.

[5] Aguirre-Mu noz Z, Pantoya ML. Engineering literacy and engagement in kindergarten classrooms. J Eng Educ. 2016;105(4):630–54.

[6] ITEEA. Standards for technological and engineering literacy the role of technology and engineering in stem education. New York, USA: Technical Foundation of America and the National Science Foundation; 2020.

[7] Nation Assessment Govering Board. Technology and engineering literacy framework for the 2018 national assessment of educational progress. Washington (DC): The National Academies Press; 2018.

[8] Lee CS. Exploring the assessment of technology and engineering literacy in the united states. Journal of Korean Practical Arts Education. 2021;27(3):137–54.

[9] Miska JW, Mathews L, Driscoll J, Hoffenson S, Crimmins S, Espera A Jr, et al. How do undergraduate engineering students conceptualize product design? An analysis of two third-year design courses. J Eng Educ. 2022;111(3):616–41.

[10] Sommer M, Ritzhaupt A. Impact of the flipped classroom on learner achievement and satisfaction in an undergraduate technology literacy course. J Inf Technol Educ. 2018;17:159–82.

[11] Voogt J, McKenney S. TPACK in teacher education: are we preparing teachers to use technology for early literacy? Technol Pedagogy Educ. 2017;26(1):69–83.

[12] Putra PD, Sulaeman NF, Supeno, Wahyuni S. Supeno, and S. Wahyuni, "Exploring students' critical thinking skills using the engineering design process in a physics classroom,". Asia-Pac Educ Res. 2021;32(1):141–9.

[13] Magarian JN, Seering WP. Characterizing engineering work in a changing world: synthesis of a typology for engineering students' occupational outcomes. J Eng Educ. 2021;110(2):458–500.

[14] Firman H, Rustaman NY, Suwarma IR. "Development technology and engineering literacy through stem-based education.," no. Icieve. 2016;2015:209–12.

[15] National Assessment Governing Board. "Technological literacy assessment and item specifications for the 2012 national assessment of educational progress.," *Contract*. p. 2012.

[16] Bampasidis G, Piperidis D, Papakonstantinou V, Stathopoulos D, Troumpetari C, Poutos P. Hydrobots, an underwater robotics stem project: introduction of engineering design process in secondary education. Adv Eng Educ. 2021;8(3):1–24.

[17] Khamhaengpol A, Sriprom M, Chuamchaitrakool P. "Development of steam activity on nanotechnology to determine basic science process skills and engineering design process for high school students.," *Thinking Skills and Creativity*. vol. 39, no. April 2020, p. 100796, 2021. https://doi.org/10.1016/j.tsc.2021.100796.

[18] Lin KY, Wu YT, Hsu YT, Williams PJ. Effects of infusing the engineering design process into STEM project-based learning to develop preservice technology teachers' engineering design thinking. Int J STEM Educ. 2021;8(1):1–15.

[19] Fraile MN, Pe nalva-Vélez A, Lacambra AM. "Development of digital competence in secondary education teachers' training," *Education Sciences*. vol. 8, no. 3, p. 2018.

[20] Falloon G. From digital literacy to digital competence: the teacher digital competency (TDC) framework. Educ Technol Res Dev. 2020;68(5):2449–72.

[21] [21] T.R. Kelley and J.G. Knowles, “A conceptual framework for integrated STEM education.,” *International Journal of STEM Education*. vol. 3, no. 1, p. 2016. https://doi.org/10.1186/s40594-016-0046-z.

[22] Usnia AM, Prasetyo ZK, Wardaya NF, Elviana R. “A preliminary study of student’s initial technology and engineering literacy,” *Proceedings of the 6th International Seminar on Science Education (ISSE 2020)*. vol. 541, no. Isse 2020, pp. 589–595, 2021.

[23] Zaini M. The effectiveness of learning implementation plan tool through design-based research. Open Psychol J. 2018;11(1):271–8.

[24] P. Anjarsari, Z.K. Prasetyo, and K. Susanti, “Developing technology and engineering literacy for Junior High School students through STEM-based science learning.,” *Journal of Physics: Conference Series*. vol. 1440, no. 1, p. 2020. https://doi.org/10.1088/1742-6596/1440/1/012107.

[25] Shakrani G. S. M., & Pearson, NAEP 2012 technological literacy framework and specifications development: Issues and recommendations. Washington (DC): National Assessment Governing Board; 2012.