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What is Science, Technology, Engineering, Mathematics (STEM) Literacy?

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***Abstract*—STEM specifically refers to science, technology, engineering, and mathematics. STEM education provided an opportunity to develop STEM literacy for the next generation. Currently, there is not an agreement of the particulars in education, or in standards that define and how to measure STEM Literacy. STEM literacy is an entity (composed of knowledge and skills) that used to understanding and creating problem solutions related to STEM context. This article will discuss the definition of STEM literacy that integrates science, technology, engineering and mathematics literacy (composed of knowledge and skills aspect), and an indicator of STEM literacy. In addition, this article also provided an overview of how to measure STEM literacy in teaching and learning.**

Keywords—STEM literacy

I. INTRODUCTION

STEM Education is a global movement in educational practice that integrates science, technology, engineering and mathematics to develop 21st century skills, such as STEM literacy [1]. STEM literacy refers to an individual's ability to apply an understanding of how tight competition works in the real world that requires interrelated science, technology, engineering and mathematics [2]. STEM literacy is a skill that needed a citizen to participate effectively in the modern workplace [3]. The National Academy of Sciences reports that students who will have STEM careers must be problem solvers, skilled in quantitative reasoning and modeling, effective in communication and cross disciplinary collaboration, and cognitive relationships between science and society [4]. The assumption show that STEM literacy is one of the 21st century skill which should be promoted.

Currently, researchers have explored STEM literacy in education. Zolman state that STEM literacy should not be viewed as a content area but composed of skills, abilities, factual knowledge, procedures, concepts, and metacognitive capacities that to gain further learning [5]. Wagner, et al. studied science laboratory activity to foster STEM literacy [4]. This study state that STEM literacy of non-STEM majors can be increase by on textualizing the lab with a meaningful issue of local, national, and global interest and connecting it to some of the social challenges of sustainability.

STEM literacy became entity that have important to promote in science teaching and learning. However, there is not researcher that study about how to measure this skills. There is not agreement by particular education, or in standard that define STEM literacy and this domain. This article will discuss about the framework of STEM literacy and how to assess its.

II. METHOD

The method used in the literature review is traditional reviews. Researchers was identified articles about STEM literacy from international journals and books. Articles were chosen based on several criteria, including: indexed articles in Scopus, ERIC, Web of Science and Springer. We set data range of inclusion from 2010 to 2018. In addition, the articles was explained the theory of STEM literacy, STEM literacy assessment, and strategies used to enhance STEM literacy. The criteria for the book used are the research on STEM literacy, philosophy of STEM literacy and standards about STEM literacy. Based on selected sources, the researchers made a synthesis of the concepts, theories and assessments of STEM literacy.

III. STEM LITERACY

A. The Framework of STEM Literacy

STEM Literacy framework builds on Ong & Mclean descriptions that composed literacy of Science, Technology, Engineering and Mathematic separately [6]. Zolman state that STEM literacy composed of skills, ability and knowledge [5]. Based on conception of STEM literacy, author develop the STEM literacy framework (see Figure 1). In this model, that there are three main component of literacy: science, mathematics, and technology & engineering. Equally important to the model are the interactions between and among these bodies of literacy, represented as STEL (Science technology & engineering literacy), MTEL (Mathematic technology and engineering literacy), SML (Science mathematic literacy), and STEM literacy.

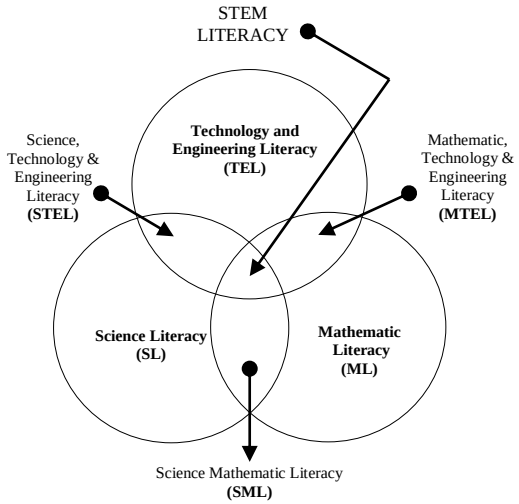

Fig. 1. The framework of STEM literacy.

Science literacy refers to an individual's: scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues; understanding of the characteristic features of science as a form of human knowledge and enquiry; awareness of how science and technology shape our material, intellectual and cultural environments; and Willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen [7].

Mathematical literacy is an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognize the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens [7].

Technology and Engineering Literacy (TEL) defined capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solutions and achieve goals. TEL is interrelated domains that composed: Technology and Society; Design and Systems; and Information and Communication Technology [8].

Science & Mathematic Literacy (SML) refers to an individual's ability to use knowledge (in science and mathematics) and processes to understand, and additionally, to participate in decisions that affect science and mathematics in life, environment, and technology. SML is interrelated domain science and mathematics literacy.

Mathematic, Technology & Engineering Literacy (MTEL) refers to an individual's ability to use mathematic and engineering principles to develop and evaluate technology to developing solutions and achieving goals. MTEL used to understand technology is created by mathematics and engineering principles to solve problems and make decisions.

Science, Technology & Engineering Literacy (STEL) refers to an individual's ability to use science and engineering principles to develop and evaluate technology that needed to develop solution and achieving goals.

STEM literacy is an ability to adapt and accept change driven by the work of new technologies, in anticipation of the multilevel impact of their actions, to effectively communicate complex ideas for various audiences, and perhaps most importantly, to find calculations and creativity in solving an unimaginable problem now [9]. STEM literacy also defined as an ability to identify, apply and integrate the concepts of science, technology, engineering, and mathematics to understand a problem and innovate to solve the problem [10].

Bybee state that STEM literacy refers to an individual's [10]:

- Knowledge, attitudes, and skills to identify questions and problems in life situations, explain the natural and designed world, and draw evidence-based conclusions about STEM related-issues;
- Understanding of the characteristic features of STEM disciplines as forms of human knowledge, inquiry, and design;
- Awareness of how STEM disciplines shape our material, intellectual, and cultural environments; and
- Willingness to engage in STEM-related issues and with the ideas of science, technology, engineering, and mathematics as a constructive, concerned, and reflective citizen.

National Governor's Association states that STEM literacy is an interdisciplinary research area that lays down all four areas, technology, engineering and mathematics. STEM literacy is not simply interpreted as the achievement of literacy in all four aspects. It emphasized an ability to apply understanding of how the world works within and across the four interrelated domains of science, technology, engineering and mathematics [11].

STEM literacy is a skill that used in authentic work and socio-scientific of scientist work on 21st century. The contemporary of scientist is supposed to be able to bring knowledge, insight and analytical skills to bear public interest issues such as potential natural disasters and technology [12].

The STEM literacy should not be viewed as a content area but consists of skills, abilities, factual knowledge, procedures, concepts and metacognitive capacities to achieve further learning. STEM literacy can't be interpreted as a separate definition of science, technology, engineering and mathematics (silos) [5]. STEM literacy did not interpreted achieving literacy in all four STEM fields, but it is an interdisciplinary skill that overlaps concepts and processes [13].

The perspectives on STEM literacy can be additionally understood by considering the nature of an individual who is STEM-literate [14, 15]. Abts identified four indicators of someone who is STEM-literate: (1) problem-solver, (2) interdisciplinary thinker, (3) self-reliant, and (4) technology capable [14]. Meeder also noted the problem solving aspect,

but additionally identified conceptual knowledge of STEM subjects, connecting STEM content to STEM careers, and psychological aspects of achieving in STEM [15].

Based on the above assumptions, the authors argue that STEM literacy is a skill that can't be viewed as a knowledge of science, technology, engineering and mathematical literacy separately. STEM literacy is a competency that consist of content' knowledge (science, technology, engineering & mathematic) and interdisciplinary skills component used to solve problems in daily life.

B. Organizing Domain of STEM Literacy

STEM literacy involves more than just the content of knowledge; but requires an understanding of the representation and interpretation of scientific data, scientific explanations and projects as well as the process of science. STEM literacy require cognitive and metacognitive skills, collaborative teamwork, effective use of technology, and an ability to engage in scientific discussions on global issues, synthesize different concepts, and influence others to take action based on scientific evidence information.

For assessment purposes, the author define of STEM literacy may be characterized as consisting of three domain that adopted from assessment of TEL (see Figure 2). The first domain of STEM literacy is content areas. Content areas on STEM literacy composed of: 1) Science, technology & society; 2) Design & system; and 3) Mathematic. Science, technology and society refer to students' knowledge regarding relation of science, technology & society and impact on environment. Design refer to students' knowledge regarding a process that used to develop new technology and solve problem. Mathematic refer to students' knowledge regarding how to identifying and translating problem or solution into mathematical language.

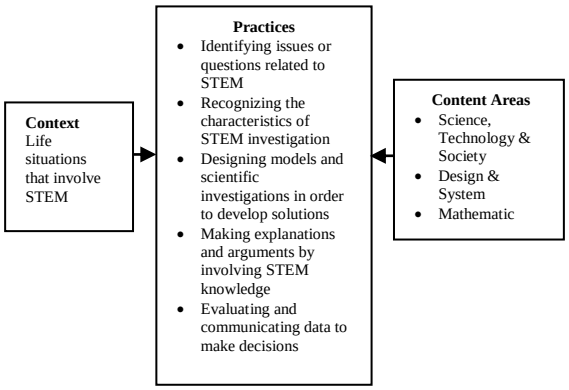

Fig. 2. Domain of STEM literacy.

The second domain of STEM literacy is practices. The practices on STEM literacy helps students understand: how scientific knowledge & technology develops, and the work of engineers. These practices also helps students understanding of integrating science, technology, mathematic and engineering. This practice makes students' knowledge meaningfully and elaborate it more deeply into their worldview. Specifically, the practice of STEM literacy includes activities such as the following:

- Identifying issues or questions related to STEM
- Recognizing the characteristics of STEM investigation
- Designing models and scientific investigations in order to develop solutions
- Making explanations and arguments by involving STEM knowledge
- Evaluating and communicating data to make decisions

Finally the third domain of STEM literacy is contexts. The contexts of STEM literacy emphasizes situations in everyday life involving science, technology, engineering and mathematics. The contexts roles as stimulus. The stimulus is a question or problem in everyday life that needs to be solved by applying the knowledge and skills. Therefore, the contexts chosen as an issue that needs to be addressed by requiring individuals to apply their knowledge and skills.

C. How to Measure STEM Literacy

In accordance with the STEM literacy definition, test (item) questions require the use of practices in context by involving content areas. Assessment of STEM literacy evaluate students' knowledge in the three content and five practices. The context of STEM literacy is not included in the assessment.

Table 1 that presents the basic components of STEM literacy for assessment in a way that can be used to relate the domain with the structure and the content of assessment units. Table 1 may be used both synthetically as a tool to plan assessment exercises. The first step to construct assessment units, we could consider the contexts as stimulus material, the STEM literacy practices required to respond to the questions or issues, or the content areas to the exercise.

TABLE I. DEFINITION OF CONTENT AREAS AND PRACTICES ON STEM LITERACY

	Content Areas		
	Science, Technology & Society	**Design**	**Mathematic**
	Students' knowledge regarding relation of science, technology & society and impact on environment	Students' knowledge regarding a process that used to develop new technology and solve problem	students' knowledge regarding how to identifying and translating problem or solution into mathematical language
STEM LITERACY PRACTICES	• Identifying issues or questions related to STEM • Recognizing the characteristics of STEM investigation • Designing models and scientific investigations in order to develop solutions • Making explanations and arguments by involving STEM knowledge • Evaluating and communicating data to make decisions		

A test unit is comprised of a group of independently scored questions (items) of various types, accompanied by stimulus material that establishes the context for the items. Many different types of stimulus are used, often in combination, to establish the context, including passages of text, photographs, tables, graphs, and diagrams, often in combination.

The assessment used to measure STEM literacy involves the context as possible and shows the complexity of real-world problems. The authors adopt the PISA assessment structure that use of situations or contexts for some questions rather than asking several questions separately for a number of different situations. Characteristics of questions that can be used to assess stem literacy are: 1) The questions can be provided with some information or data in various forms of presentation to be processed by students who will answer it; 2) The questions presented should prompt students to process (relate) the information in question; 3) The question are presented in varied form (multiple choice, short field, or essay); and 4) The question includes the application context.

IV. Conclusion

STEM literacy can't be viewed as a mastery of science, technology, engineering and mathematics separately. STEM literacy is a 21st century skill that composed interdisciplinary knowledge and practices which used to solve problems in everyday life related to STEM features.

The framework of STEM literacy provide an opportunity for researchers to assess the ability of stem literacy (by considering the domain of STEM literacy) of students in different countries that have applied STEM-based curriculum. This framework also makes it easier for teachers to make assessments that are used to assess students' STEM literacy. For curriculum developers, the existence of this framework provides an overview of the indicators of students who are STEM literate. Therefore curriculum developers can develop a teaching and learning process oriented to the domain of STEM literacy.

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