



## Developing Sustainability Literacy Through STEM Learning: A Review

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### Abstract

The future of human life is not only full of potential and development but also of challenges. Global challenges that will be faced start from the environmental crisis, poverty and social problems. The UN has formulated bold goals through 17 targets in the Sustainable Development Goals to deal with this sustainability problem. The education sector is a milestone in achieving these goals. Through education, sustainability can be achieved among other things by integrating design thinking into STEM learning which can promote sustainability literacy. This opportunity need to be follow up to develop Sustainability Model of Design Thinking as one innovation to enhance sustainability literacy.

**Keywords:** Climate Change, Design Thinking, STEM Education, Sustainable Development, Sustainability Literacy

### Introduction

The Global Risk Report stated that there are threats risking the development in the future. Out of five risks, four are related to environment (World Economic Forum, 2019). While there is an emerging awareness of the current environmental issue on education provision and learning, it is also clear that education has an important role to play in addressing this change. This includes work carried out using various terms and definitions, including 'education for sustainable development' or ESD (Sterling, 2001).

In 2015, the United Nations Development Programme (UNDP) identified a series of seventeen important worldwide goals referred to as the Sustainable Development Goals (SDGs). These goals make up a blueprint for the future well-being of the globe oriented around the themes of people, planet, prosperity, peace, and partnership (United Nations, 2019). Education is a crucial part

of the SDGs, not only due to its role as a specific goal (Goal 4: Quality Education) but also because it is essential to the possibility of progress on all goals, including environmental-related goals (UNESCO, 2014).

Access to quality education in STEM is linked to reduced poverty, economic growth, and more resilient democracies; these disciplines play an essential role in addressing many of the Sustainable Development Goals (SDGs). International organizations, such as USAID and UNESCO have moved STEM education to the forefront of their institutional goals as careers in STEM fields are projected to see exponential growth in the twenty-first century (UNESCO, 2017).

The integrative capability of engineering design is evident in the engineering design process, which is a

problem-solving method that engineers use—along with knowledge from science and mathematics—to solve technological challenges (NRC, 2009). Beside that, the literacy should be delivered through empathy. Empathy is a stimulus that

## **Review**

### **Sustainability Literacy (SL): Four Ways Thinking**

Experts have broadened the understanding related to sustainability to more specific environmental issues by pointing out the ecological relationships that exist between human-nonhuman interactions and flora and fauna with land (Kates et al., 2001; Orr, 1992). To deal with this problem, education must be a central component to improving the human condition. The main focus is on preparing the next generation to make decisions, identify problems, and solve them.

Literacy is a collection of skills that can create a certain level of competence that can be measured in the future after being achieved and formed. The term literacy is defined as, "a collection of skills that enable effective participation and influence in various areas of social life" (Stibbe & Luna, 2009).

Nolet (2009) defines sustainability literacy as various advanced abilities and actions such as problem solving and information-based decision making. Likewise, the concept of sustainability literacy stated by Tilbury (2011) not only states new knowledge but also learns to: (a) ask critical questions; portray a more positive future; think systematically; and to explore the relationship between tradition and innovation". Teachers who have acquired sustainability literacy need to be empowered to end society with a critical lens; (b) teach students sustainability topics and ways of thinking; (c) make the right decisions; (d) contribute to cultivating intrapersonal, interpersonal, intergroup and intergroup concepts of society and the

connects students with a party or condition, this is a feature of the design thought process that is different from the engineering design process (Cook & Bush, 2018).

environment (Bertschy et al., 2013; Nolet, 2009; Stibbe & Luna, 2009). Together with other literacy, teachers must be able to inculcate sustainability literacy into everyday learning in every curriculum (Santone et al., 2014).

Four ways of thinking (future thinking, value thinking, systems thinking, and strategic thinking) that are more steps or collections of knowledge that must be acquired. Rather, it is a conceptual framework for analyzing sustainability problems and solutions through an interconnected approach. These four specific ways of thinking were identified by a review of the existing literature. Somehow this way of thinking is discussed in many literatures, but still stands respectively (Wiek et al., 2011; Stibbe & Luna, 2009; Bollmann- Zuberbuhler et al., 2014).

Future Thinking is also known as anticipatory thinking, foresight, or trans-creating thinking. Sustainability requires future thinking. This includes, "the ability to analyze, analyze, and create a comprehensive picture of the future related to sustainability issues" (Wiek, et al., 2011). Future thinking allows an anticipatory approach to understanding, reducing, and/or adaptively preparing for future changes, problems, and solutions (Gibson, 2006).

Value thinking is also considered as thinking based on values, knowledge orientation, and/or ethical thinking. Since sustainability is a problem-oriented field

and shopping by solutions, potential solutions are value thinking. This includes, "the ability to collectively map, define, apply and negotiate sustainability values, principles, goals and targets" (Wiek et al., 2011, p. 209). Thinking values in the concepts of justice, equality, socio-ecological integrity, and ethics. It also means understanding how these concepts vary across cultures, and how integrating these concepts contributes to solving sustainability problems.

Systems thinking is also known as interconnected thinking or holistic thinking. According to Wiek et al. (2011) System thinking, "is the ability to collectively analyze complex systems across multiple domains (society, environment, and economy) and at multiple scales (local to global), thereby considering systemic effects. Systems thinking does not necessarily require knowledge. In fact, systems thinking is about assessing the level of complexity of a system and analyzing system dynamics to make informed decisions that reduce risks with negative outcomes.

Strategic thinking means being able to develop a strategy or plan to achieve a

### **Education for Sustainable Development through STEM Learning**

Students, teachers and parents need to be helped to possess environmental and scientific literacy by improving a powerful and sustained implementation of future-oriented science, technology, engineering, and math (STEM) learning focused on the issues of critical importance as those outlined in the UN SDGs against societal and health problems such as climate change that can adversely affect their lives (O'Donnell, 2018). STEM learning can be identified as one of the new approaches to be used in the education system, which also aims for students to be able to solve problems in their daily lives.

certain vision. Strategic thinking shapes every decision in order to be able to contribute to achieving a vision. Strategic thinking is, "the ability to collectively design and implement, intervene, transition, and transformative governance strategies towards sustainability" (Wiek et al., 2011, p. 210). It involves considering possible solutions through a specific set of assumptions, suggesting potential alternative solutions, and proposing existing assumptions and alternatives, which can potentially lead to new solutions that may be more appropriate (Lawrence, 1999). Strategic thinking involves using analogies and qualitative equations to create new ideas in addition to developing new learning-dependent actions (Lawrence, 1999).

Teachers must be able to take a global perspective to encourage students to see that problems, people, cultures and places of life are interconnected and that complex systems operate at multiple levels. Likewise, teachers need to provide critical thinking skills, which are directly related to decision-making abilities (Church & Skelton, 2009).

Technology used in STEM learning is increasingly accessible, intuitive, reliable, and diverse in its application, and it is becoming possible for each student to be educated in a way and at a pace that suits his or her abilities, interests, and needs (Barak, 2014). STEM Learning can enhance conceptual understanding, and promote higher-order thinking skills among students (Barak, 2014).

STEM learning is also called upon to participate in the social process of searching, learning, and shaping to solve global sustainability issues and to critically reflect on their contribution to sustainable

developments. STEM knowledge and the process of science can help understand global problems and support actions in society that address them in a meaningful and knowledge-based way (Pahnke et al., 2019).

Inquiry in STEM learning allows students to explore 'hands-on', to experiment, to ask questions, and to develop responses based on the reasoning in addition to solving problems, and understanding the phenomena of the real world around them ('minds on'), just as scientists and engineers do. Exploration and exploration-based and inquiry-based learning are paths to knowledge for students, on which they can build up knowledge and skills. (O'Connell, 2014). Besides conceptual knowledge, an essential part of basic education in the STEM

**Empathy as the Main Gate**

STEM learning is essential for developing globally connected innovators in the 21st century (Garner et al., 2017). However, the STEM field generally focuses on developing students' science, engineering, and technology competencies without discussing the emotional relationship students have with STEM learning processes and products (Garner et al., 2017; Gunkel & Tolbert, 2018).

There are several factors that influence student interest in STEM, but the main factor is the relationship between empathy and STEM problem-based learning activities in the classroom (Gunkel & Tolbert, 2018; Wirkala & Kuhn, 2011). Providing opportunities for students to improve learning by involving empathy and a global perspective can increase interest in science learning (Garner et al., 2017).

Problem-based learning (PBL) and design thinking (DT) activities can provide opportunities for students to determine what they want to solve and how they will combine critical thinking and problem-solving skills to develop designs or

learning is the ability to acquire, expand, critically reflect on, and apply knowledge using suitable methods of thinking and acting. This includes the ability to work out fundamental relationships for oneself, to evaluate these relationships, and to make decisions based on them, and also, to develop skills in using the ICTs (Haus der kleinen Forscher Foundation, 2016).

From all the above, it can be understood that STEM learning can encourage changes in knowledge, skills, values, and attitudes to enable a more sustainable and just society for all. It aims to empower and equip current and future generations to meet their needs using recent effective tools and a balanced and integrated approach to sustainable development

products as solutions (Barton & Tan, 2018; Bush & Cook, 2019; Bybee, 2010; von Solms & Nel, 2017; Wirkala & Kuhn, 2011). This activity also provides a way for students to develop and practice creative thinking skills such as asking questions, making relationships, showing empathy, collaborating with peers, and experimenting (Akçay, 2017; Cook & Bush, 2018; Wagner, 2012).

Experts describe empathy as an important impact factor of Design Thinking (Brown, 2008; Kouprie and Visser, 2009; Kolko, 2011). They argue that empathy is a very important form of insight that comes from interactions with other people. Therefore, these insights are not the result of mere analytical processes (Grotz and Creuznacher, 2012).

As a basic form of social cognition, empathy is the capacity to share and experience the feelings of others (Greenson, 1960). Empathy is a skill that enables us to understand other people's situations and perspectives, both imaginatively and affectively (Rogers,

1975). The process of passive speech empathy or feelings towards others (Bialystok & Kukar, 2018; Nelems, 2018). Empathy has a definition, but traditionally, empathy is defined as putting oneself in the other party's position (Bialystok and Kukar, 2018; Nelems, 2018).

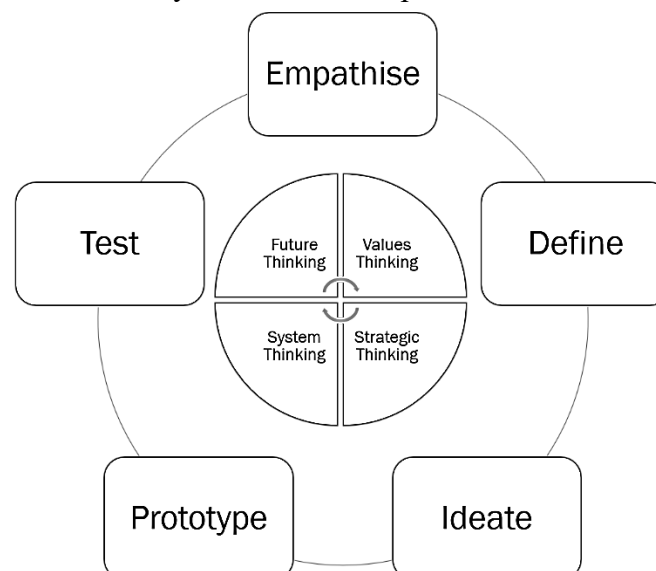
Empathy is a stimulus that connects students with a party or condition, this is a feature of the design thought process that is different from the engineering design process (Cook & Bush, 2018). Through design thinking, students get the feeling of confidence in their ability to make changes

that have a positive and sustainable impact globally (Carroll, 2014). Design thinking is able to encourage students to take advantage of their unlimited imagination (Carroll et al., 2010). Mehalik et al (2008) and Scheer, Noweski, and Meinel (2012) show a study in which design thinking activities based on science learning can be useful in increasing higher learning outcomes, encouraging class interaction, motivating, and expressing oneself in class, design thinking develops creativity for students to be able to connect and contribute in finding solutions to sustainability problems.

### Sustainability Model of Design Thinking: A Way Forward

Design thinking which consists of five stages, namely Empathize, Define, Ideate, Prototype, and Test, is one of the fastest ways to increase creativity (Plattner, 2018). This model is designed to improve critical thinking skills and creative problem solving needed to translate ideas from sketches to prototypes. During the “empathize” and “define” phases, students engage directly with their peers to understand local community needs

regarding challenges directly related to sustainability. Alternatively, this model could draw on students' specific knowledge about their local community to involve them in STEM activities. In the "ideate" and "prototype" phases, students work in teams to find solutions and use feedback to organize their designs. Students then present the design matrix, describe resource constraints, and receive feedback from peers.



**Figure 1.** Connection between Design Thinking and Sustainable Literacy in STEM Learning

Integrating design thinking into STEM learning to develop sustainability

literacy (Figure 1) can help overcome many of the current challenges limiting SDG



progress. While these types of difficult challenges are relatively new to science (Bojo'riquez-Tapia et al. 2017). This integration is a great opportunity to achieve the SDGs efficiently and effectively in the

## Conclusion

The diagram of sustainability model of design thinking provides a space where new knowledge about sustainability can be placed. This conceptual model articulates concrete abilities and teaching strategies to link pedagogy and learning with sustainability literacy goals. This model can provide rich insights into the key elements that should be incorporated into STEM learning for sustainability. It can also serve as a guide for meaningful assessment and evaluation of sustainability units, lesson plans, and activities. This model embodies the knowledge, skills and attitudes required for problem solving with respect to complex sustainability challenges.

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midst of the complexities of the real world. It also can produce sustainability initiatives that are effective, transformational, and well-integrated into unique socio-ecological contexts.

Based on the importance of sustainability literacy to achieve the SDGs target through STEM Learning, integration of design thinking into STEM learning to acquire sustainability literacy need to further develop. Other opportunities to support teachers in using STEM learning to develop sustainability literacy are by providing teaching materials with various context issues, guidelines for developing learning tools so that teachers are more independent, and policies that motivate teachers to improve sustainability literacy.

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