# Integration of STEAM into Science Education for Sustainable Development

T. M. Sakunthala Yatigammana Ekanayake

*Department of Education, Faculty of Arts, University of Peradeniya*

## Introduction

As a response to a growing concern about human society's impact on the natural environment, the concept of sustainable development emerged. The concept was defined in 1987 by the Brundtland Commission (formally the World Commission on Environment and Development) as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). This definition acknowledges that sustainable development should happen without a negative impact on the capacity of the natural environment in order to meet the present and future needs of human beings, while development processes may be necessary to meet human needs and enhance the quality of life are being made. This indicates that sustainable development seeks human well-being without stretching ecological limits. Furthermore, 17 sustainable development goals (SDGs) aiming to set attainable targets that can be achieved as a 2030 agenda for sustainable development were adopted in 2015, at the General Assembly of the United Nations (UN). These SDGs are further decomposed into 169 targets, and there are currently about 230 indicators that have been proposed for realizing these targets. According to the sustainable report 2027 (Jeffrey D. Sachs & Christian Kroll, 2021) achieving the SDGs requires success in realizing six major transactions: Quality education (SDG 4); access to good quality and affordable health care (SDG 3); renewable energy and circular economy (SDGs 7,12, and 13) sustainable land and marine management (SDGs 2,14, and 15); sustainable urban infrastructure (SDGs 6,9, and 11); and universal access to digital services (SDG 9). In short, the Agenda is a universal call to action to eradicate some factors and they are poverty, protect planet Earth, and ensure that all people live in peace and prosperity. Considering these factors, it is clear that education has to play a key role in inculcating a comprehensive positive understanding, especially among the young generation in achieving sustainable development Goals. This was already emphasised at the UN World Summit in Johannesburg in 2002, where the reorientation of current education systems was outlined as key to sustainable development. Education for sustainable development (ESD) promotes the development of the knowledge, skills, understanding, values, and actions required to create a sustainable world, which ensures environmental protection and conservation, promotes social equity, and encourages economic sustainability. The aim of this article is to explore how science education with the integration of STEAM approach could support sustainable development. STEAM is simply defined as an interdisciplinary approach to learning, which can deliver academic concepts coupled with real-world lessons as students apply science, technology, engineering, mathematics, and arts. Therefore, this article first discusses science education, then STEAM education, and finally it describes how science education with the integration of the STEM approach supports the process of sustainable development.

## Science Education

The term science has been defined from many perspectives but in common, they all address similar characteristic features. Setiawaty et al (2018) define science as knowledge, which is initially acquired and developed based on experiments. That means science is not just the acquisition of knowledge but also a process of discovery. In parallel to that Kalantzis (2005) views science as highlighting several key elements: science has a basis in lived experience and also has an empirical foundation, Science builds theories that model the world and develops frames of reasoning and explanation, Strong science also analyses the world, Science is application-oriented and at its best, science is inventive and innovative. The Cambridge Advanced Learner Dictionary (2012) defines science as the "*knowledge obtained from the systematic study of the structure and behavior of the physical world, especially by observing, measuring and experimenting, and the development of theories to describe the results of these* *activities*." Further, science deeply influences every aspect of human life. The expert given in the Microsoft Encyclopaedia Encarta (2003) describes that science helps to understand objects and systems that are related to our everyday life and therefore learning science is very important.

"*From its early beginnings, science has developed into one of the greatest and most influential fields of human endeavor. Today different branches of science investigate almost everything that can be observed or detected and science as a whole shapes the way we understand the universe, our planet, ourselves, and other living things* (p.82)."

As a result, science has been able to acquire a permanent place in the school curriculum in all countries throughout the world. Further, the literature provides evidence to show that to have a meaningful experience in science, it should not happen only inside the classroom and may be outside | (Reiss 2007) depending on the appropriate pedagogical actions and decisions. For instance, to provide opportunities to have fruitful science learning, it should extend to the places where the students can learn science authentically in real contexts. Moreover, science education essentially aims to systematically develop and sustain learners' curiosity about the world while enhancing scientific thinking and understanding of how natural phenomena in the world can be explained (Das and Amrit, 2014; Harlen et al, 2015). Further, the processes and content of science are of great importance to everybody in their day-to-day life, which has been defined from different angles by scholars as the aims of science education. In line with that, Trna and Trnova (2016) present three concepts of science education;

(A) Awareness of science in current, social, globally relevant, and occupational contexts in both educational and out-of-school settings, enhancing emotional personality development and basic skills

(B) Intellectual education in interdisciplinary contexts refers to an engagement with science, its terminology, methods, basic concepts, interdisciplinary relations, findings and their perspectives, which enhance individual intellectual personality development

(C) General science-related education and facilitation of interest in the contexts of nature, everyday life, and living environmental issues which take up and promote students' interests, enhancing general personality development and education.

Moreover, according to Halen (1999), preparing students for a career in science (pre-professional training) (ICUS, 2011; Chief Science Advisor-NZ, 2011), preparing the young generation for their adult roles as citizens, employees, managers, parents, volunteers, and entrepreneurs (Trna and Trnova,2016), building students' capacity for innovation and creativity (Chief Science Advisor-NZ,2011) and developing Science Process Skills (SPS) are among the major goals to be achieved in science education. Altogether, the aims of science education can be summed as, scientific literacy, individual benefit, democracy, social justice or socio-political action, and criticality (Reiss, 2007). In addition, Holbrook (2010) raises the fact that "school science education needs to respond to a changed social context and to help prepare young people to contribute as citizens to shaping the world in which they will live". Moreover, scientific literacy through science education is required by each and every individual in modern society since it influences every moment of life. ASPIRES (2013) also ensures that the population has a good level of scientific literacy (understanding of science) is also very important not only because it is good for the economy, but also because it can benefit individuals and communities economically and socially, helping to promote active citizenship and enabling people to participate in, and shape, scientific and technological developments in society. The promotion of scientific literacy has been recognized as a major goal of school science education in the world (Turiman et al., 2012, Holbrook,2010) and it is nurtured by quality science education (ICUS, 2011).

Most researchers and science educators agree that students must not only know a body of information about science, but also they must be able to do a range of scientific tasks and processes. Elaborating on this further, (Newton, 1988) claims that science education consists of two components: the content and the processes. The content of science includes laws, facts, and theories, and the processes of science consist of observing, measuring, recording,

**processing** data, hypothesizing, communicating and discussing, investigating, trying things out, handling things, watching, and monitoring (Wellington, 2004). Considering the teaching of science, in order to support students' scientific understanding, two interrelated areas, namely understanding of content and processes should be developed (Braund, 2008).

Science process skills can be interpreted as adaptations of skills used to study a problem, a concept, or a phenomenon in a systematic manner to compile knowledge, find answers and make conclusions. Students are directed to observe, classify, measure, use numbers, guess, conclude, and communicate the object being studied during science lessons. In addition to that, students are also guided to identify variables, form hypotheses, define variables into operational forms, experiment, interpret data, and draw conclusions. Hence, Science process skills are defined as tools that acquire information about the world (Gultepe,2016) and on the other hand is also defined as problem identifiers, formulation of the hypothesis about the problem, making a valid prediction, identifying and defining of variables, designing and experiment to test the hypothesis (Kamba et al,2018). It is well recognized that the pedagogical approaches used by teachers have to play a major role in providing opportunities for students to obtain knowledge and skills in science learning. The recent research literature provides evidence that the support of the STEAM approach for teachers in creating such a meaningful and safe learning environment.

**STEAM**

SMET Education which evolved out of the American government policy in the early 1990s, within the National Science Foundation [NSF] (Deghaidy et al, 2016) was later redefined as 'STEM' (Koonce, Zhou, & Anderson, 2011, Deghaidy et al, 2016). Historically, the Morrill Act of 1862, World War II, and the launch of the Soviet Union's Sputnik triggered the initiation of STEM Education in the USA, aiming to provide all students with critical thinking skills that would make them creative problem solvers and ultimately more marketable in the workforce (White, 2014). Today, all nations require a knowledgeable, skilled, and innovative workforce to be competitive in the ever-changing knowledge-based economy of the 21st century. Hence, there is a strong consensus among stakeholders in every field, especially in education and economics on the importance and development of STEM education. The acronym STEM stands for the four primary discipline families of Science, Technology, Engineering and Mathematics (Koonce, Zhou, & Anderson, 2014) and it is commonly used to describe education or professional practices in those areas (McDonald, 2016). As White (2014) states STEM can have different meanings to different people and basically, definitions for STEM fall into one of two domains: education or occupation (Koonce, Zhou, & Anderson, 2014). Accordingly, from the educational point of view STEM education includes the knowledge, skills, and beliefs that are collaboratively constructed at the integration of science, technology, engineering, & mathematic content subject of its epitome of interdisciplinary education (Lapek, 2018) or it may sometimes be referred in the literature and government reports encompassing the teaching of individual curriculum areas of science, digital and design technology, mathematics (Honey, Pearson and Schweingruber,2014).

According to the literature it has proved that STEM education can be applied in all educational stages including the Montessori (preschool) stage. As emphasized by Granovskiy, (2018), typically STEM education includes educational activities across all grade levels from preschool to post-doctorate in both formal (classrooms) and informal (after-school programs) settings. Authentic STEM education is expected to build students' conceptual knowledge of the interrelated nature of science and mathematics, in order to allow students to develop their understanding of engineering and technology (Hernandez et al., 2014). In other words, students acquire the knowledge and skills learned in two or more STEM disciplines that are applied to real-world problems and/or used to deepen understanding and find the most suitable solution.

The importance of STEM educational implementations is emphasized by scholars in several studies. They energize the learning environment, revitalizing the curriculum with real-world relevance and establishing connections to everyday life experiences while fostering creativity, problem-solving, and critical and higher-order thinking. Moreover, such a learning experience empowers the student to cope with multifaceted and complex real-world problems in the future as they essentially require multidisciplinary understanding. As well it has identified and proven that knowledge and competencies gained studying science, mathematics, engineering and technology is essentially useful to build up individuals to meet the challenges of the 21$^{st}$ century globally. As well they are proficient enough to meet the demands of 21$^{st}$-century workplaces.

According to Feng-Day (2017) STEM education only concerns the project itself (what and how to do), While ignoring the concern for the person itself and the background (who does and why), so STEM in the breadth and depth of interdisciplinary knowledge there are still some limitations. All these resulted in the transformation STEM into STEAM, where A stands for arts.

At present, there is a growing emphasis on STEAM, which engages students in the subjects of science, technology, engineering, arts, and mathematics. As Dell' Erba, (2019) defined, it is an approach to teaching, in which students demonstrate critical thinking and creative problem-solving at the intersection of science, technology, engineering, arts, and mathematics. According to Yakman (2008), the founder of STEAM education, STEAM is a developing educational model of how the traditional academic subjects (silos) can be structured into a framework removing the boundaries between each by which to plan integrative curricula.

On the other hand, STEAM education directs students to collaborative problem-solving (Herro et al, 2017) through interdisciplinary thinking (Jia, Zhou, and Zheng, 2021) and collaborative learning. Collectively all these processes develop students '21$^{st}$-century skills, referring to the knowledge, skills, and character traits that are deemed necessary to effectively function as citizens, workers, and leaders in the 21$^{st}$-century workplace (Bryan et al., 2015).

**Science education with the integration of STEAM, toward sustainable development**

As discussed above it would be worthwhile to think about how the integration of STEAM into science education would open more avenues to obtain meaningful learning experiences that support sustainable development by promoting the development of the knowledge, skills, understanding, values, and actions required to create a sustainable world, which ensures environmental protection and conservation, promotes social equity and encourages economic sustainability.

Science education while integrating STEAM appropriately can be offered to enhance the quality of education. For instance, while integrating STEAM students are offered more avenues to learn science in an overall view while interrelating to other disciplines in the real context as an actively engaging collaborative activity that provides meaningful learning. Furthermore, the integration of STEAM allows teachers more space get pedagogical decisions and actions to provide learning experiences in students centered approach (Kurshan and McManus,2017). This approach develops students' communication skills, decision-making skills, team working skills, reasoning ability development of ideas and solutions which are essential components in 21st-century skill and competency development. Moreover, by integrating STEAM, a science teacher can provide more opportunities for students to learn science while empowering them to be curious learners who seek creative solutions to take thoughtful risks, engage in meaningful learning activities, become resilient problem solvers, embrace and appreciate collaboration and work through the creative proces .

As mentioned above science is a subject that can be taught while incurring curiosity among students. The integration of STEAM opens more opportunities to the teacher to get pedagogical actions in creating learning activities while incurring students' curiosity about the world while enhancing scientific thinking and understanding of how natural phenomena in the world can be explained (Das and Amrit, 2014; Harlen et al, 2015). Not only that by integrating STEAM, as the teacher provides opportunities for students to acquire the knowledge and skills connecting to two or more STEM disciplines that are applied to real-world problems helps to deepen understanding and find the most suitable solution for the given problem. This experience will contribute to a positive impact on sustainable development.

The integration of STEAM energizes the learning environment of the science classroom, revitalizing the curriculum with real-world relevance and establishing connections to everyday life experiences while fostering creativity, problem-solving, and critical and higher-order thinking definitely contribute the sustainable development.

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*__Sakunthala. Y. Ekanayake__ is a Professor in the Department of Education in the Faculty of Arts at the University of Peradeniya, Sri Lanka. She received her Ph.D. from the Graduate School of Education, the University of Bristol, the UK in 2011. She is also the Head of the Department of Information Technology of the Faculty of Arts, University of Peradeniya. She is the vice president of the Indian Ocean Comparative Education Society and a member of the editorial team of the Global Comparative Education, Journal of the WCCES. She has published more than 40 papers in journals and conferences, authored three books, and also co-authored six books. She was conferred with a commonwealth fellowship at the University of Bristol in 2016. Her current research interest focuses on the use of mobile phones for teaching and learning, Pedagogy, E-Learning, Science Education, and Comparative Education.*

**Themed Collection**

# Sustainable Development Goals and the Role of Chemists and Chemical Sciences

N. M. S. Hettigedara

*President, Institute of Chemistry Ceylon*

## Background

One of the most important and remarkable events in the 70-year history of the United Nations (UN) was the declaration of 17 Sustainable Development Goals (SDGs) on 25 September 2015. Through this declaration, 193 member states of the United Nations which includes Sri Lanka also, agreed on a collective global mission to transform the planet to achieve a sustainable future by with a target year of 2030. Progress towards the SDGs will be measured against 169 specific indicators. While the Millennium Development Goals declared by the UN in 2000 focused on specific problems of the world's poor and shaped the development aid policies of the richest countries, the new SDGs envisage a global vision of development for all, based on the principle of sustainability. The responsibility is shared by all the countries. At its heart are the 17 Sustainable Development Goals (SDGs), for action by all countries - developed and developing - in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and induce economic growth while tackling climate change and working to preserve our oceans and forests.

Generally, awareness of the SDGs, and their central importance is inadequate among the majority of practicing chemists or their professional bodies. The probable reason is that, the chemists too often busy themselves with short-term problems and research interests and do not see the broad picture. The International Organization for Chemical Sciences in Development (IOCD) with a deep concern for the future of both the planet and the chemical sciences, have issued a call to all their chemists to adopt the SDGs, as done by their governments and use this platform to reposition chemistry in a broader context and to ensure that chemistry plays its specific role as the central science.

## Importance of Chemistry in achieving sustainable development goals

The knowledge and products contributed by chemistry such as providing sources of energy; a host of materials including polymers, plastics, semiconductors and solid-state display devices, agents for crop protection and plant growth, pharmaceuticals and