REVIEW

# Environmental Sustainability in Science Education in the Anthropocene: A View from STEAM Education

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***Abstract**: Environmental problems in the age we live in require us to think differently, to question them, and to do something corrective. The role of science education in the transformation of education and its adaptation to the age is perhaps more than in previous periods. Because at the end of the day is the continuity of our planet. This article examines science education and higher-order thinking skills in the Anthropocene era and presents examples from studies on environmental sustainability as a prominent concept in this field. In addition, it argues that STEAM education is one of the ideal approaches that can meet this goal by presenting examples of what can be done with a holistic and interdisciplinary view of environmental sustainability within the framework of STEAM education. Suggestions are made through STEAM training, with the assumption that environmental sustainability in an intricately connected network structure rather than linear chains can only be understood with an interdisciplinary approach and solutions can be found only in this way.*

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# Introduction

THE Concept of Sustainability that has come to the Forefront in the Anthropocene Era. Anthropocene, it comes from the Greek words "anthro" meaning "human" and "cene" meaning "new (geological age)" and refers to the end of the Holocene age and a new geological age in which human activities have had a great impact on the world (Gilbert, 2016). So anymore human; it is trying to improve and change the world he lives in, and this effect is more than in the previous geological periods of the world. It is also obvious that the effect of change is mostly in the direction of harming the world. Many argue that we are in a "climate emergency" and that urgent action is necessary if we want to prevent a sudden catastrophic change (Gilbert, 2022). With the declaration of 2005-2014 as the Education Period focused on Sustainable Development by the United Nations; It is aimed to improve the cognition, perception and behavior of individuals on a sustainable lifestyle and to realize social transformations in the long term (Ozturk, 2017). In the OECD Education 2030 report, "children starting school in 2018 abandon the notion that resources are unlimited and exist to be exploited; they will need to value shared well-being, sustainability and well-being." with this expression, attention was drawn to the environmental, economic and social challenges for the future of the world (OECD, 2018). In its press release published on 14 January 2022, the European Union called for environmental sustainability to be at the center of EU education and training systems (EU Press Release, 2022). The new vision of K-12 education is that instead of telling students what the phenomenon is and then expecting them to recreate the phenomenon, it should include the role of the confounders of nature and human activity through actions, making the nature of phenomena clear (Milne et al., 2022). So much so that today there is no need to produce disaster scenarios and brainstorm with dystopian fictions, especially environmental disasters exist in our lives. In this case, the problem scenarios turned away from fiction and turned into real problems waiting for an urgent solution.

The damage caused to the ecosystem by the economic and social development experienced in the 20th century has led to the discussion of the concept of sustainability in the last half century (Bazin, 2012). Sustainability consists of three dimensions: environmental, economic and social (Bazin, 2012; Clark et al., 2019). For economic sustainability, a radical new model, the Circular Economy, is proposed instead of the linear economy based on the "buy-build-use-dispose" consumption model since the Industrial Revolution (Andrews, 2015). For social sustainability, the importance of integrating multicultural education, inclusive teaching and learning approaches into education systems emerges (Skrefsrud, 2022). The environmental dimension

is more prominent than these two concepts (Clark et al., 2019). This article also focuses on the environmental sustainability dimension.

Sustainability is a system of systems that requires a high level of understanding beyond concepts and principles (Clark et al., 2019). There are three themes (universalism, scientism, and technocentrism) common to the scientific discourse on sustainability (Feinstein & Kirchgasler, 2015). Sustainable development is shaped according to the needs in different parts of the world and in different historical periods in relation to supply and demand elements (Arslan, 2021).

Education for Sustainability is about providing real-world learning opportunities related to the change of current thinking, practice and values, and this should be a fundamental research question for all educational institutions and fields (Jacobi et al., 2016). Education for sustainability is a goal, not a tool (Albe, 2013). Education for sustainability reveals the necessity of a critical scientific education (de Freitas et al., 2022). On the other hand, there are also criticisms against the theme of sustainability. Kopnina (2020) criticizes the economy-centeredness of sustainable development and emphasizes teaching for sustainability with various examples of alternative education (indigenous learning, ecopedagogy, ecocentric education, education for steady state and circular economy, empowerment and liberation) emphasizing planned ethics and degrowth.

Doğru et al. (2019) found that interest in the field has increased since 2015, when they made a bibliometric analysis of 7 thousand studies in the field of sustainable development and education. Yıldırım (2020), who examined the educational researches in Turkey on sustainability, stated that the subject was mostly dealt with in relation to science and social studies education. Arslan (2021) as a result of his interviews with the participants (teachers, academics, non-governmental organizations, policy makers/practitioners) who have roles and responsibilities in STEM education in the context of Turkey, he made policy proposals for STEM education. Besides he suggested increasing teacher competencies, integrating STEM approach into curriculum, establishing physical infrastructure, ensuring that all stakeholders are involved in the process, the students participate in STEM careers, direct them to STEM careers, and make effective dissemination activities with an inclusive policy.

## Sustainability Concept in Science Education

One of the fundamental assumptions of science education is to provide citizens with a critical reading of the world and to reflect on their own circumstances as they face the challenges of science and technology (de Freitas et al., 2022). Although science education has been shaped by different ideas over the years, it has brought pre-vocational education to future scientists,

worked with methods familiar to twentieth-century scientists, and raised willing "science literate" citizens (Gilbert, 2016). For sustainability, it is necessary to improve science education and scientific literacy of society worldwide (Johnson, 2012).

In the Science Education Eligibility (ROSE) project, in which students in the 15-year-old age group are come up in approximately 40 countries; in many industrialized countries, it has been reported that students are suspicious of the objectivity of scientists, science is less popular than other subjects, and these negative perceptions are more common in girls (Gough, 2008). For this reason, since the role of science education is directly proportional to the perception of science and scientists, it is also important in terms of the position of science in society.

The globalization of the world and the changes in the Anthropocene age require a rethinking of science education (Gray & Colucci-Gray, 2014). Considering the end of carbonized modernity, science education is on the verge of transformation (Gilbert, 2016). To ensure sustainability, redesigning science education has become a necessity, not an option (Bateman et al., 2021). Stating that the Anthropocene can be used as an analytical lens in history and philosophy of science, Moura and Guerra (2022) stated that the nature of science studies have not yet taken the Anthropocene into account. By connecting cognitive and affective domains, it can associate understandings in the physical world with attitudes and values in the social world and provide a process that can facilitate the motivation to take conscious action (Quinn et al., 2015). At this point, environmental education issues, which can be considered as one of the dimensions of science education, come to the fore. Since there is a promising synergy between science education and environmental education, it should be ensured that environmental issues are more integrated into the learning process in science education rather than seen as a separate learning content or intermediate topics, so that both efforts enrich each other (Schönfelder & Bogner, 2020).

The basic framework of science education dedicated to sustainability; change in purpose refers to changes in the subject-object relationship, changes in content and methodological choices (Albe, 2013). Principles to be adopted in environmental education, interdisciplinarity, integrity, continuity, questioning, experientialism, inclusiveness, flexibility, local-global interaction, participation, constructivism, learning by doing-living, predictive learning and innovation (Özdemir, 2007). Scientific literacy is essential to understanding many sustainability issues and especially possible solutions to the environment (Quinn et al., 2015). Science education based on sustainability can offer channels for understanding human's relationship with the world beyond ecological benefits (Jeong et al., 2021). Science literacy for sustainability; means the development of evaluative systems thinking ability in the context of science, technology, environment and society, which requires the

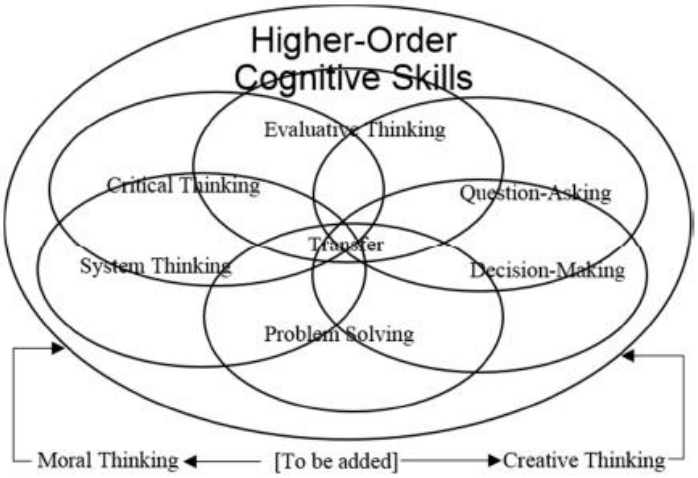


**Figure 1: Conceptual Model of Higher-Order Thinking Skills in the Context of Science Education and Sustainability (Zoller, 2015, p. 4476).**

development of students' high-level cognitive skills (HOCS), systems critical thinking, and questions (Zoller, 2012).

## *High-Level Thinking Skills in the Context of Sustainability in Science Education*

Core competencies in sustainability; are high-level skills such as systems thinking, forward thinking, exemplification, strategic competence, and interpersonal competence. These competencies are above the basic competency such as critical thinking and communication (Wiek et al., 2011). High-level thinking skills are skills that cause teachers to push and expand their abilities in flexible and rich teaching environments and require radical changes in teaching practices (Zohar, 2013). As seen in **Figure 1**, high-level cognitive skills such as critical thinking, systems thinking, problem solving, decision making, asking questions, evaluative thinking, and transferring; considered within the framework of moral thinking and creative thinking.

System thinking, community participation, multidisciplinary thinking, cross-discipline transfer, and strong foundations of discipline should be involved in order to solve the problems of the 20th century with the understanding of the 21st century (Rogers et al., 2015). It can be thought that systems thinking and interdisciplinary thinking are particularly prominent concepts.

## *What can Science Education do for Environmental Sustainability?*

Few studies have focused on the future-thinking potential and futurism of science education (Rasa et al., 2022). Scientific studies in recent years. It increasingly emphasizes the diversity and locality of scientific practices, moving away from the idea of a single scientific method approach or universal method (Albe, 2013). Locality should be addressed in science education and culture should be comprehensively included in science education (Zidny et al., 2020). When Ateş (2018) examined the Science 2018 curriculum in Turkey, he stated that the achievements related to sustainable development were 10.82 percent and should be increased.

One of the important fields of study in which environmental sustainability can be discussed in science education is socio-scientific issues. As socio-scientific issues bring up the science-human interaction, students' tendencies are at the center of curriculum outcomes (Tytler, 2012). Socio-scientific issues are influential in the potential role of science education in thinking and acting about the future (Rasa et al., 2022). Colucci-Gray et al. (2006) have combined the term socio-scientific issues one step further with systems thinking using the term socio-environmental.

Science education practices that center sustainability has been on the agenda for a long time. Sustainable Schools in Australia such as Eco Schools, Green Schools; it deals with waste, energy, water and biodiversity (Gough, 2008). Birdsall (2013) determined that as a result of the sustainability education program he conducted with New Zealand students, their understanding of sustainability and science literacy developed and they showed behavior as activists. Laird (2017) gave the Montessori-inspired Edible School Garden project as an example and suggested the project to sustainability education by giving children a chance to meet with the open air. Şeker (2017) concluded in his experimental study with secondary school fifth grade students that the science education program for sustainable development had a positive effect on academic achievement and views on sustainable development. In an experimental study conducted in a kindergarten in Sweden, it was pointed out that children's imaginations offer different solutions that can be beneficial to sustainability-related problems (Caiman & Lundegård, 2018). Levrini et al. (2019) stated that the climate change teaching module they conducted with 12th grade students in Italy improved students' perceptions of building the future. In a study conducted in Iran, it was revealed that when primary and secondary school students were asked to draw pictures for the future, children who thought they could have an impact on the environment drew optimistic utopian pictures, while sedentary children who did not accept responsibility drew dystopian pictures (Demneh & Darani, 2020). Trott

and Weinberg (2020) concluded that thanks to sustainability-based science education, children's attitudes towards science improve, understanding the scientific and social dimensions of climate change expands their view of science, and the urgency of climate change solutions makes it more interesting and important for children. As seen in these examples, "what kind of future awaits us and what solutions?", "we can create for future solutions on problems?" like questions are closely related to the sustainability perception of today's children.

A science education that addresses the challenges of today can be decisive in creating the future when children are provided with the space to be critical actors for sustainability in their society (Trott & Weinberg, 2020). To put it more bluntly, the world of tomorrow may be just as much in the minds of today's children. Evans & Marianne Achiam (2021) drew attention to out-of-school learning environments in sustainability education and stated that museums, science centers, zoos and aquariums have strong potential for promoting sustainability.

# Environmental Sustainability in STEAM Education

Arguing that environmental education is one of the STEM disciplines, Geidel and Winner (2016) explained the reason for this; they explained that environmental science is based on the scientific method and discovery process, is empirical and predictive, is meticulous in providing certain skills for analytical analysis, and provides students with critical thinking skills. Interdisciplinary dialogue is considered as a necessity for addressing contemporary science issues in society and as a tool for questioning the focus boundaries of thought categories and methodologies (Colucci-Gray et al., 2013). Scientists need to be prepared interdisciplinary both in their field of science and in data science (Pennington et al., 2020). Colucci-Gray et al. (2013) suggest interdisciplinary approaches to sustainability education. Pedagogical design, socio-efficiency and philosophy are the main themes in sustainable interdisciplinary education (Daneshpour & Kwegyir-Afful, 2022). Bateman, Steele & Sexton (2021) stated that students should work as "sustainability engineers" in science classes. Levrini et al. (2019) stated that future-oriented STEM education, which is still in its infancy, should become a new trend. Integrating disciplinary views can contribute to reconnecting with and feeling included in nature (Colucci-Gray et al., 2013). As seen in **Figure 2**, the integrative approach, as opposed to the reductionist approach, can enable the development of an environmental sustainability view by addressing more than one way of thinking.

There are studies on STEM education that focuses on sustainability. Clark & Button (2011) carried out a study in sustainability that brought together public schools, art museums, non-governmental organizations, gov-

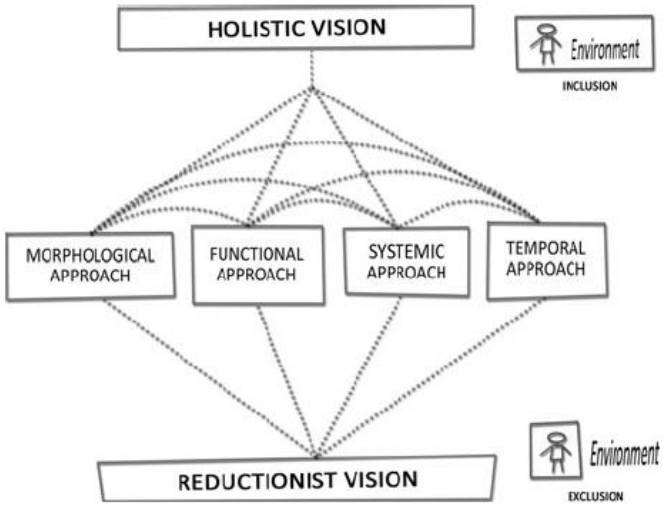


**Figure 2: Integrative Approach to Nature (Colucci-Gray et al., 2013).**

ernment officials and the general public under the umbrella of STEM. They concluded that by learning from each other, the participants gained a broad and deep understanding of human-environment relationships and the effects of humans on natural resources. Rogers et al. (2015) carried out studies designed to connect perspectives from different disciplines with technical reports from other classes and to write short technical reports summarizing students' results with STEM activities in modules containing inclusive questions. As a result of the studies, they stated that the students' understanding of the characteristics of the twenty-first century problems related to sustainability has improved. Caughman (2017) stated that in STEM education, sustainability education-themed courses affect students' science identities positively and contribute to permanence in science. Kudo et al. (2021) stated that there are four learning outcomes after interdisciplinary sustainability-oriented courses in higher education: Examining assumptions, managing misunderstanding and miscommunication, mutual learning, being empathetic and looking at life through the eyes of local people. Arısoy (2021), in her research aiming to raise awareness of sustainable life at an early age, implemented a training program in which they tried to find solutions to daily life problems for Sustainable Development Goals in STEM design workshops. Uslu & Boz Yaman (2021) helped secondary school students to come up with an engineering design for the reuse of wastewater in the activity called "Environmental Siphon Activity", which was considered as a STEM project. Campbell and Speldewinde (2022) pointed out that the game-based learning

of young children can be compatible with STEM and sustainability and drew attention to the importance of the subject even in early childhood.

The literature shows the lack of educational models that combine arts and sciences to encourage communities to think about sustainability, and STEM can fill this gap (Clark and Button, 2011). STEM; it deals with the world located at the intersection of science, art and society clusters (Clark & Button, 2011). Heras et al. (2021) set an example for the interdisciplinary collaboration of scientists and artists with their art-based sustainability studies. Trott et al. (2020) propose three methods for combining art and science:

- *Interdisciplinary learning focusing on local sustainability challenges;*
- *Participatory process that combines experiential knowledge with research-based knowledge;*
- *Co-operative sustainability action that invites community members to design and implement sustainable alternatives where they live.*

Smith & Watson (2019), who are critical of STEM education due to its emphasis on economic growth and technology, suggested that it be expanded to include critical reflection and future dimensions and strengthened with STEAM education. Finley (2014) and Feinstein & Kirchgasler (2015) propose an approach that combines the complementary pedagogical strengths of the two fields with a systematic collaboration between science educators and social studies educators for sustainability challenges. STEAM education also emphasizes this. STEAM education has been created with the solution of animation by bringing a new breath to the problems of fragmentation of disciplines and science teaching (Trott et al., 2020). Finley (2014) suggested that 3-4 week interdisciplinary Anthropocene projects can be developed with the cooperation of different fields such as physics, earth sciences, social sciences, and life sciences.

# Conclusion and Suggestions

Changes in the vision and mission of science education in the Anthropocene era have led to the concept of environmental sustainability. Addressing environmental sustainability through science education in k-12 grades and being one of the main sources of argument can activate higher-order thinking skills. Environmental sustainability is addressed through approaches such as socio-scientific issues, inquiry, out-of-school science teaching, project and problem-based learning, and has a wide coverage in the literature.

As an interesting example, Bateman et al. (2021) likened beavers to an ecosystem engineer, and stated that they created a suitable habitat for others while eliminating the space of some organisms by building a dam. An environment without human influence provides the balance within itself.

However, as a result of the harmful activities of human beings, the balance is disturbed and can lead to irreversible disasters. Considering that man is only one of the parts of the system in the light of systems thinking, the negative perception of dominance over nature can be seen. For this reason, it is important to gain this knowledge, thought and sensitivity from childhood through educational means.

STEM/STEAM education, which has left its mark on the last years of science education with its holistic approach, is also involved in finding solutions to our problems in the Anthropocene and applying it. In particular, the artistic and social emphasis of STEAM education can function as the socio-scientific perspective of STEM, providing a humanistic, holistic and developing perspective to our age. By conceptualizing STEAM in the Anthropocene, interdisciplinarity should be approached in a way that enables us to connect with people, try to break down disciplinary hierarchies, and embrace emerging tensions (Guyotte, 2019). In STEAM education at all levels, students should be exposed to many complex and pressing issues of the Anthropocene and interdisciplinary issues (Guyotte, 2019). In this context, it is suggested that STEAM education and the concept of environmental sustainability should be examined interdisciplinary and practices should be carried out with students at the k-12 level.

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