

STEM Education and Environmental Sustainability

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Chapter Highlights

This chapter summary provides the reader with a quick overview, summarizing the key points from the chapter addressing STEM education and environmental sustainability.

- Essential Components of STEM Education – It combines science, technology, engineering and mathematics in an interdisciplinary manner.
- Environmental Sustainability Context – STEM has an important role in finding solutions to environmental problems such as climate change, biodiversity loss and resource depletion.
- Impact on Learning Outcomes – STEM-based sustainability projects improve students' academic achievement, environmental awareness, problem-solving and critical thinking skills.
- Pedagogical and Applied Approaches – Methods such as project-based learning, the maker movement, nature-based learning and outdoor laboratories are integrated with STEM and sustainability.
- Future Directions and Recommendations – The integration of technologies such as artificial intelligence, big data and IoT into education, curriculum reforms, teacher training and the dissemination of school-based sustainability practices are important steps towards the future in education.

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Introduction

The complexity of the environmental and social dimension of global issues on climate change, biodiversity loss, depletion of natural resources in such a short time and environmental degradation has increased as ever today. As such, these challenges for practitioners need to be tackled not only through conventional methods of education but also demand interdisciplinary and holistic approaches (Christie et al., 2015). To this end, it provides students with scientifically thinking and a more sensitive attitude toward environmental issues (Rahmadayanti & Fielardh, 2024).

In recent years, STEM education has become the focus of education policies of many countries. This approach usually stands out in order to support economic development and increase global competition (Xie et al., 2015). However, it is known that STEM practices that focus only on economic benefits are not sufficient in producing sustainable solutions to today's environmental and social problems. Therefore, integrating STEM education with the understanding of environmental sustainability is seen as an important issue for educators and administrators (Han et al., 2022). Gaining an understanding of environmental sustainability helps students understand nature-related systems, recognize problems and develop solutions (Christie et al., 2015). When this approach is combined with STEM education, students can effectively use many skills from scientific thinking to engineering design, technological tool use to mathematical analysis to solve environmental problems (Istiana et al., 2023).

This study reveals the relationships between STEM education and environmental sustainability; presents a theoretical framework for how these two fields can be integrated and provides information on possible application areas. Thus, it is revealed how the relationship between STEM education and environmental sustainability is shaped at what points. In addition, this section includes detailed evaluations on the future development of the subject, its applicability and effects in various situations.

Definition and Importance of STEM Education

What is STEM?

STEM refers to the fields of science, technology, engineering and mathematics within an educational system. Disciplinary integration was initially proposed by Judith Ramaley (2001) in the field of education in USA, and the studies focusing on the integration of these fields have been gaining speed recently (Roehrig & Karışan, 2022). STEM pedagogy teaches

students to develop creative, realistic responses to complex social and environmental problems, with an integrated approach to various branches of science together (Kennedy & Odell, 2014).

In recent years, there has been a dramatic increase in the volume of research on STEM education. This has largely been an experimental and descriptive content, both identifying the training processes to teachers, and their success on the other hand regarding their students (Daşdemir et al., 2018; Karaşah-Çakıcı et al., 2021; Suherman et al., 2025). There is international literature on the integration of STEM and other fields. Researches have shown that projects based on real-life problems, engineering design processes and learning opportunities that involve different disciplines are very valuable for students (Bryan et al., 2015). It is mentioned that integrated STEM projects raise student engagement, reinforce students' ability to apply and transfer knowledge protean, and allow them to learn distinct domains concurrently and more effectively (Capraro et al., 2013).

According to Holmlund et al. (2018) STEM education is the learning of using the fields of science, technology, engineering and mathematics together to solve a problem one faces in everyday life. In this respect, it can thus be claimed that students not only learn about these disciplines but also promote their interdisciplinary thinking skills. Similarly, according to Akgündüz et al. (2015), STEM represents a type of educational approach in which students learn how the knowledge they have acquired through various domain disciplines fits together as a whole and apply this knowledge to resolve the problems in their real life.

STEM education maintains a disciplines based common framework and allows a holistic based learning which is truly connected with life. By this means the students look at a complex problem from various angles (Hasanah, 2020). The application of scientific methods in the learning process enables students to acquire experience of creation of solutions of real-world problems (Savage et al., 2008). In contrast, design thinking opens up the space for creative ideas, builds prototypes of best-practice examples, and rigorously tests those prototypes (Lin et al., 2021). In addition, STEM projects carried out with group work improve students' communication skills. These projects also make it easier for students to adopt leadership roles and work together (Shamuganathan, 2023).

The Interdisciplinary Nature of STEM

The prominent feature of STEM education is that it considers fields such as

science, technology, engineering and mathematics as a whole. This approach aims to develop students' creative thinking, critical analysis and problem solving skills (Akarsu et al., 2020). For example, science teaches observation, hypothesis formation and experiment design (Zhan & Niu, 2023). Technology shows ways to collect information, analyze and present data (Yaşar-Ekici et al., 2018). Engineering makes solution production systematic and improves design-oriented thinking (Aşık et al., 2017). Mathematics strengthens numerical thinking and supports solution processes in other disciplines (Bulut et al., 2024).

The interdisciplinary nature of STEM gives students the habit of thinking about information obtained from different fields together. Thanks to this approach, students develop not only their technical skills, but also their ability to think creatively, critically evaluate and create multifaceted solutions to complex problems (Akarsu et al., 2020). Since real-life problems usually involve more than one variable, students' ability to evaluate different aspects at the same time makes it easier for them to analyze the situation more accurately. On the other hand, in STEM projects, students develop themselves not only with academic knowledge, but also with social skills such as working together, exchanging ideas and communicating effectively (Bybee, 2013).

21. Century Skills and STEM

Today's rapidly changing technological structure and the global interaction environment expect individuals to have not only technical knowledge, but also multidimensional skills such as digital literacy, critical thinking, effective communication, creative thinking and working together (Holmlund et al., 2018). STEM education increases the ability of students to analyze complex situations they face and develop solutions (Nguyễn et al., 2025), at the same time supports innovative thinking through design-based applications (Sarıkoc & Ersoy, 2022). In addition to giving students the habit of acting as a team, group studies conducted during this process also help students to share their thoughts and communicate effectively by understanding each other (Savage et al., 2008; Akarsu et al., 2020). In addition, thanks to the active use of digital tools, students become not only consumers of technology but also conscious and productive users (Yaşar-Ekici et al., 2018).

The basis of STEM activities is for students to gain the skills of analyzing problems that they may encounter in real life, structuring the solution process in a planned way and developing effective solutions. In this process,

where critical thinking is used actively, students not only repeat ready-made solutions but also become more effective in developing creative ideas. On the other hand, STEM projects often require teamwork, which is important for students to develop their social skills such as working together, exchanging ideas and achieving common goals (Yıldırım & Altun, 2015). These skills acquired through STEM not only contribute to individual success; they also contribute to the process of producing solutions to problems encountered at the societal level (Han et al., 2022). Therefore, associating the STEM approach with broad-ranging issues such as environmental sustainability can both support individual consciousness development and contribute to the general benefit of society.

Introduction to Environmental Sustainability

The Concept of Sustainability

The sustainability concept defined by the Brundtland Commission in 1987 indicates meeting present needs without compromising the ability of future generations to meet their own (Christie et al., 2012). This definition highlights the need to address both its environmental and social/economic components when considering sustainability. The study of Demirel and Sungur (2018) noted together with the environment, society and economy, sustainability in education should be regarded as well. Furthermore, education are important to provide environmental consciousness and sustainable lifestyle that can include in education materials (Gülersoy & Civil, 2023).

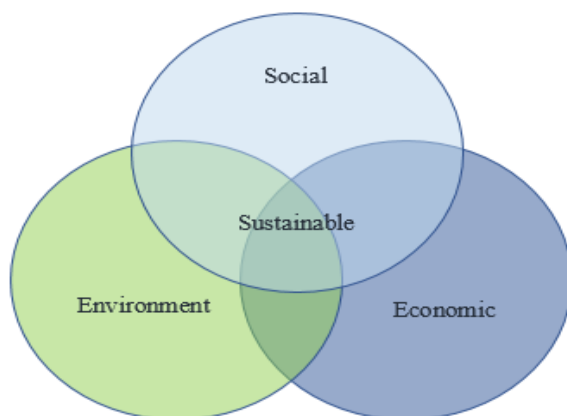


Figure 1. Interaction between the environmental, social and economic dimensions of sustainability (Purvis et al., 2019)

In international literature, the integration of environmental education and STEM is now starting to gain some attention (González-Gómez et al, 2021; Guzmán-Cedhalla et al., 2020). It has been observed that the E-STEM (Environmental-STEM) approach is effective in raising student environmental awareness and thus increases the probability of adopting environmentally sensitive behavior (Helvacı & Helvacı, 2019). In other study Malecha (2020) investigated the STEAM approach which integrated education for the environment and art shows that this integration increased creativity and environmental awareness of students. The basics of sustainability consist of three dimensions: environmental sustainability, social sustainability and economic sustainability. Figure 1 shows the dimensions of sustainability and the interaction between them:

Environmental Sustainability

Environmental sustainability, as an understanding that allows people to exist in a balanced way with nature, aims to support the continuity of the planet's ecosystems without disturbing them. This means maintaining the conditions necessary for natural systems (climate, water cycles, biodiversity etc.) to be self-renewing. The main purpose here is to manage natural resources in a way that is sensitive to the needs of today's and future generations, without depleting them. Sustainability refers to the appropriate utilization of natural resources to keep ecosystems viable (Rockström et al, 2009).

There are four components of environmental sustainability. These are: the sustainable production of clean energy, conservation of biodiversity, the sustainable use of resources and sustainable management of natural systems. Arguably the most vital step to decrease the impacts of climate change, especially global warming is to decrease the carbon emissions from energy generation and utilization together with implementation of carbon capture technologies (Warszawski et al., 2021). On the other hand, conservation of biodiversity and sustainable use of resources and proper water and land planning, helping to maintain healthy ecosystems and food security is another critical situation in this context (Foley et al., 2011; Cardinale et al., 2012; Kirchherr et al., 2017).

Social Sustainability

Social sustainability is a social paradigm in which people show the ability to meet their needs and have their rights covered. It is a structure that enables people to participate in decision-making. Having such aspects

of social and cultural identities in place naturally creates a social structure that also enriches the idea of the individual in the society hence, it is based on recognition of other vital cultural identities and contributes to building the society (Eizenberg & Jabareen, 2017). The theory of social sustainability is in equality, justice and social inclusiveness. This theory aims to narrow the gap in income, opportunity and identity among people (Boström, 2012). It is crucial for all people to have access to healthcare, live in a clean environment, and live in safe living conditions. These are crucial issues that impact individuals' physical and mental health (Vallance et al., 2011). Furthermore, individuals' ability to have a say in decisions that directly affect their lives should be supported through democratic participation processes (Agyeman & Evans, 2004). Lifelong activities, particularly in education, enhance individuals' knowledge and skills related to sustainability while also strengthening the abilities needed for social cohesion and innovative solutions (UNESCO, 2017).

Economic Sustainability

Economic sustainability means conducting economic activities in a way that does not harm human, environmental, or social well-being. It is the concept of prosperity for few in the long view at the expense of many. Nature and social justice must not be trampled by economic systems and actions. Financial sustainability is only one part of economic sustainability. That also means more sharing in wealth, and sharing in our resources so that our resources will last for the generations to come. It is about sustainable, equitable prosperity — not endless growth (Daly, 2005).

While the transition from fossil fuels to clean energy is a crucial issue for the environment and sustainability, it is crucial that the emergence of new job opportunities during the transition does not exacerbate differences between social classes (Ürge-Vorsatz et al., 2014). Sustainable production and consumption patterns are a key element in reducing the negative impact of economic activities on the environment. Similarly, sustainable production and consumption practices have a positive impact on people's quality of life (Geissdoerfer et al., 2017). Beyond existing approaches to measuring economic growth, wealth, and well-being, more comprehensive measurement methods that encompass different dimensions are needed (Costanza et al., 2009).

Environmental Issues and the Role of STEM

In this century, humanity has faced serious environmental issues

including climate change, biodiversity loss, deforestation, global warming or ocean acidification and resources depletion of natural water. This gets the natural cycle out of whack and destroys peoples' quality of life. The problem has become so large and expansive that it is going to take the collective work of multiple fields to help solve this. It is essential to approach the problem from a scientific paradigm, integrating technological innovations, engineering perspectives, and mathematical analysis. Environmental problems profoundly impact not only nature but also economic structures and social life. Due to the multifaceted impact and magnitude of the issue, national and international cooperation is crucial in developing strategies for a sustainable future (United Nations, 2022; IPCC, 2023).

In this respect, STEM education enables students to become aware of environmental issues and develop innovative solutions. Through this process, they are able to develop practical ideas around environmental problems applying scientific thinking, problem solving and design skills. While science helps understand natural events and the functioning of ecosystems, fields such as climate change, ecology and environmental chemistry play a fundamental role in helping students understand environmental systems better (Christie et al., 2015). In technology, students are allowed to develop solutions and designs to environmental issues. In this regard, renewable energy, ecofriendly materials, waste and environmental monitoring tools is prominent (Bărbulescu et al., 2025). Students with an engineering background can support their ideas in producing ecological designs that do not destroy the environment (Han et. al., 2022). Mathematical model is employed to comprehend complex environmental processes and to generate future scenarios. Models, especially those related to climate systems and ecosystems, are very effective in predicting the risks that may be encountered (Li et al., 2013).

Connection with the United Nations Sustainable Development Goals

In 2015, the United Nations set the post-2015 Sustainable Development Goals (SDGs) for global sustainable development with specific targets and indicators to be achieved by 2030 (United Nations, 2015). Here, there are 17 global goals under the banner of Sustainable Development Goals (SDGs) and targets stated in a variety of areas from poverty to quality education, gender equality to clean energy and combating climate change through sustainable cities and conservation on land and sea. They fully account the environment, economy and social development. It allows for countries to pursue more fair, equal, and sustainable plans of development (Sachs et al.,

2019). It is an objective that must unite all parties both public sector and civil society organization and citizens. Doing so will contribute to a planet that is able to develop in ways that are more efficient, strategic and effective (Griggs et al., 2013). This highlights that sustainability is a question of both ecology but also people and economy (Sachs et al., 2019). The visual for the United Nations Sustainable Development Goals (SDGs) icons is presented in Figure 2.



Figure 2. United Nations Sustainable Development Goals (SDG) icons (United Nations, 2015).

STEM education plays an important role in the implementation of many of the SDGs. Some of the SDGs directly associated with STEM are as follows:

SDG 4 - Qualified Education: STEM education contributes to quality education by providing students with the skills required by the era, such as critical thinking, problem solving, collaboration and effective use of technology (Bybee, 2013; UNESCO, 2021).

SDG 6 – Clean Water and Sanitation: Issues such as efficient and sustainable management of water resources, monitoring of water quality and development of treatment systems are among the main areas where knowledge and skills in STEM fields are applied (UNESCO, 2021).

SDG 7 – Affordable and Clean Energy: Topics such as the design of renewable energy systems, energy efficiency applications and energy storage solutions are technology and engineering-based studies in which STEM education is strong (UNESCO, 2021).

SDG 11 – Sustainable Cities and Communities: Many projects that support sustainable urban life, such as smart city applications, environmentally friendly transportation systems and green building designs, require the collaboration of different STEM disciplines (UNESCO, 2021).

SDG 13 - Climate Action: STEM education helps to understand climate change and develop solutions in this area. Environmental monitoring technologies and climate modeling are concrete examples of this process (Anderson, 2013).

SDG 14 – Life Below Water & SDG 15 – Life on Land: Protecting natural life, sustaining biodiversity and monitoring ecosystems is possible through environmental studies conducted with STEM. (Rockström et al., 2009; UNESCO, 2021).

The Interaction Between STEM Education and Sustainability

Scientific Literacy for Sustainable Development

Scientific literacy has been defined as the extent to which one is able to read and understand science, including using that knowledge to make informed decisions about everyday life (Holmlund et al., 2018). “It’s really important that people can do this because so many of the big environmental issues are becoming more complex and you need to be able make good judgments based on good science.” However, scientific literacy goes beyond mere knowledge. Scientific literacy encompasses not only the acquisition of knowledge but also the application of that knowledge to daily life and the adoption of sustainable lifestyles. With these characteristics, scientific literacy enables individuals to be more sensitive and solution-oriented to global problems such as environmental pollution, climate change, and biodiversity loss (Vijayatheepan, 2023). STEM education offers a multidimensional perspective and contributes to the development of scientific literacy. This approach has several key components:

Scientific Process Skills: The goal is to equip students with skills fundamental to science, such as observation, prediction, hypotheses, design of experiments, and analysis. Students will develop these skills while being encouraged to be more scientific in their thinking through a series of STEM-based activities. Furthermore, these practices not only improve procedural skills but are also linked to students’ academic success (Gürsoy et al., 2023).

Evidence-Based Thinking: Hasanah (2020) states that STEM education facilitates students in honing their skills in decision-making, such as analyzing scientific data and scientific information and supporting these with reliable evidence. Thanks to these skills, students can recognize information pollution, especially in issues related to the environment, and make evaluations based on the right sources.

Systems Thinking: Environmental problems often arise when many interconnected factors come together. To cope with such problems, individuals are expected to have a mindset that can understand the relationships between systems. Demssie et al. (2023) state that systems thinking plays an important role in achieving sustainability. Different practices help individuals not only to gain knowledge, but also to grow up as individuals who can use knowledge effectively.

Coping with Uncertainty: Scientific knowledge is not static; it is constantly renewed and developed. STEM education develops students' ability to make decisions in uncertain situations and act with incomplete information (Christie et al., 2012).

Environmentally Sensitive Approaches with Technology and Engineering Solutions

Technology and engineering knowledge have an important role in finding innovative and permanent solutions to environmental problems. In addition, by supporting the development of problem solving and design-oriented thinking skills, it makes it easier for individuals to make decisions in accordance with sustainability principles in the future (English, 2016; Kelley & Knowles, 2016). In this context, STEM programs include different engineering-based and technological applications that support environmental sustainability. Below is a summary of the key areas of these applications:

Green Technologies: STEM-based education makes it easier for students to gain an idea about energy-saving systems, renewable energy sources and environmentally friendly technologies. Solar energy panels, biofuel production, wind turbines and electric vehicles are prominent examples of this field. These mentioned technologies not only provide structures that enable alternative energy production, but also make significant contributions to environmental sustainability by reducing carbon emissions (Panwar et al., 2011; Bărbulescu et al., 2025).

Sustainable Design: Sustainable design in engineering aims to minimize

damage to the environment while also using resources more efficiently. In this process, it is important to prefer environmentally friendly alternatives in the material selection of products and to adopt the circular economy approach (Han et al., 2022). In this way, students get into the habit of evaluating an engineering product not only in terms of its technical function but also in terms of its environmental impact. These skills support individuals in making more conscious choices in areas such as sustainable production or building design in their future lives (Mulder et al., 2012).

Environmental Monitoring and Control Systems: Today, it's possible to collect and transfer environmental information faster, more effectively, and more easily. Certain applications, such as remote sensing techniques, sensor-based tools, and geographic information systems, can facilitate multi-dimensional environmental monitoring projects, such as air pollution, water quality, climate change, and natural disaster risk. By using these systems, students are able to demonstrate a highly sophisticated approach to environmental awareness (Savage et al., 2008; Hayat et al., 2019).

Waste Management and Recycling: Waste management and recycling is vital for the protection of our environment. In this context, STEM education focuses on promoting the new promising solutions that can be developed. It would also benefit the conservation of natural resources and alleviate environmental damages by implementing composting approaches and evolving recycling strategies that can achieve reversible synthesis of biodegradable materials (Kök, 2021).

Creative STEM-Based Solutions to Ecological Problems

STEM education helps students develop original and realistic solutions for the environmental challenges that will occur throughout their lives. In this practice, skills (design thinking, problem solving and creativity) are utilized simultaneously (Beers, 2011; Hilton & Honey, 2011). Shamuganathan (2023) suggests that through nature-inspired approaches like biomimicry, natural systems can be studied and solutions developed. Smart city technologies, for instance, are utilized to create and/or sustain energy, transportation, water management and waste management systems (Akarsu et al., 2020). Additionally, water management techniques such as rainwater catchment and purification save water consumption sustainably (Yaşar-Ekici et al., 2018). Such apps enable students to develop environment-friendly technology and social consciousness.

Examples of Educational Applications and Project-Based Learning

Sustainability Themed STEM Projects

Project-based learning supports students in gaining practical experiences by bringing together their knowledge and skills in different fields (Krajcik & Shin, 2014). STEM based projects not only provided them with the appropriate knowledge but also the opportunity to practice cooperation study, creative thinking, problem solving and critical thinking (Capraro et al., 2013). These sustainability projects provide students with the opportunity to implement innovative, creative solutions to environmental issues. In addition, they support the intellectual aspect of the student and also fosters social awareness (English, 2016). Hence it is easy to see why the project-based STEM initiatives stand out as a viable pathway for students to keep connected with their personal and social growth.

Globally, project-based learning has a strong currency in sustainability education. This method creates active participation of the students and produces diverse classes that are learner-centered (Cörvers et al., 2016; Kricsfalussy et al., 2018). For instance, the students could investigate energy usage of school buildings and create energy conservation methods for them (Aşık et al., 2017). Students can design use strategies on reduceable and recyclable waste (Çoruhlu & Nas, 2018) and carry out projects in the fields of biology with hydroponic systems for the projects to combine agricultural urbanism (Cummings & Cummings, 2021) on engineering and chemistry applied areas.

The Maker Movement and Environmental Approaches

The Maker movement is a method that helps students participate actively in their own production process and therefore learn. This initiative, which links STEM education and sustainability, empowers students to devise solutions to environmental issues and increases awareness of sustainability. One such initiative is known as Maker's Asylum, which has shown tens of thousands of individuals the ropes of hardware design, digital manufacturing and sustainability in India. These kind of projects not only provide a context for sensitivity of students towards environment but also for solution-oriented thinking (Saari et al., 2021) with four main applications, this is a summary of to understand the impact of the maker movement in the domaine of the sustainability. They are: 3D printing and sustainable materials, electronic waste recycling, open-source design and local manufacturing.

3D Printing and Sustainable Materials

In the maker spaces, students use 3D printing for prototyping with environment-friendly material. Innovative 3D products that have less ecological impact are made with bio-degradable polymers and recycled filaments than the conventional plastic (Agrawal Bhat, 2025). Additionally, recycling the waste plastics including high density polyethylene (HDPE) to fabricate filaments may also save energy and facilitate transformation of plastic product model towards circular economies scenarios (Oyinlola et al., 2023). They expose students to sustainable production processes and to sustainable extraction of local inputs.

Electronic Waste Recycling

Maker spaces integrate environmental awareness and ingenuity by repurposing components sourced from discarded electronic equipment. As an example, e-waste toolkit enables access for fabrics with e-waste materials, particularly in low- resource or marginalised areas to enable participants to discover socially-oriented designs alongside individual designs (Vyas et al., 2023). These practices do not only contribute to the creative problem-solving of students, but also the systematic and innovative alternatives within the scope of solid waste management.

Open Source Designs and Local Production

The maker movement promotes the sharing and dissemination of innovations and ideologies based on open source principles. This thereby promotes nearer-to-consumer production and shorter supply chains. For instance, RepRapable Recyclebot is an open-source filament extruder that reprocesses recycled plastic into filament, which not only reduces carbon emissions of long-distance transport of manufacturing fleet but also considerably saves manufacturing cost (Woern et al., 2018).

Interdisciplinary Approaches and Nature-Based Learning in STEM Education

Integrated Use of Science, Mathematics, Engineering and Technology

A key principle of education based on the STEM is an interdisciplinary approach where students can apply knowledge from different disciplines in a connected and systems/holistic way (Holmlund et al., 2018). It is an instructional approach where the teaching and learning of science, technology, engineering and mathematics are integrated in such a way that

the contribution of each subject area is interrelated and students have more comprehensive learning experience. As an illustration, in one of the solar energy projects, the students would integrate different physical concepts to electronic circuits and develop engineering solutions for system effectiveness, using the mathematical tools to perform the calculations (Han et al., 2022).

Cross-curricular work may also help students connect the dots on challenging problems, for example when it comes to specific environmental problems like climate change and waste management. Addressing such issues necessitates the interdisciplinary transfer of science, technology, engineering and mathematics (Akarsu et al., 2020; Nugraha et al., 2024). Systems thinking, design-based approaches, and sustainability are all commonly used concepts that can help to bridge knowledge across disciplines and produce an effective solution to a problem as it encourages teamwork (Roehrig et al., 2021; Wu et al., 2024). Hence, It is not merely a vehicle for transferring knowledge between disciplines, but also contributes greatly to skills such as analytic thinking, creativity, and application. Projects that are real-life and holistic design lead to greater success in learning in STEM areas (Holmlund et al., 2018; Akarsu et al., 2020; Roehrig et al., 2021; Han et al., 2022; Nugraha et al., 2024; Wu et al., 2024).

Learning with Nature: Outdoor Laboratories

Nature-based learning embodies the connection between STEM education and ecological sustainability, and it promotes engaging and direct methods of learning from and with nature (Christie et al., 2015). Biodiversity observations, water and air quality measurements in local ecosystems, or investigations of local effects of climate change help students personally experience environmental problems (Toran, 2016; Yaşar-Ekici et al., 2018); while greenhouse systems built in the garden of the school allow students to recognize sustainable agriculture and observe it (Gulhan, 2023; Kanosvamhira, 2025), solar panels and small-scale wind turbines give students a good idea of energy production processes and technology (Cole, 2023). Direct exposure relating to actual practice of scientific process skills empowers learners in the analysis of data, enhances their confidence in data collection and interpretation, leading them to a more informed perspective on environmental issues.

System Thinking Skills and Ecological Awareness

Systems thinking is a holistic way of thinking that makes the study of environmental education issues complex. This mode of thinking recognises

the wider system in which a problem is embedded and the interconnections between the elements that constitute this system, instead of analysing the problem in isolation (Arnold & Wade, 2015). Given that many environmental problems are complex, systems-oriented problems with both social and ecological components, fostering a systems perspective can be beneficial to attain solutions in these realms (Williams et al. 2017). Taking a system approach, seen as an integral part of environmental education, may help students to appreciate the relationships among human behaviour and nature. This capacity enables them to design deep rather than shallow responses to wicked environmental problems (Stave & Hopper 2007). It is even greater when considered as an instrument for understanding causes, and also the potential effects of global environmental problems which are more comprehensively defined as climatic changes, loss of biodiversity and natural resources depletion, therefore it demonstrates how the system thinking approach in which scientific thinking is being revealed, so this consciousness acquired with assistance of scientific thinking approach in environment issues help pupils learn how to use this treasure chest information not only for solving such problematic issues that were associated with environment but regularly in their daily lives (Elmas et al., 2021).

The function of ecosystems provides a quick feedback system and it is good for simplifying the training system thinking on the part of student body. It is through a study of interactions that students will be able to evaluate the effect humans have on these systems at an even greater level whilst considering how all living and nonliving things are interrelated to each other. Such an outlook allows students to reach beyond contemporary consequences of global problems and find a future direction for their lives. Since the concept of cycles and processes like carbon and water cycle have the potential of being inspiring metaphor for students, they can understand the relationship among natural system (Soderquist & Overakker, 2010; Tidball & Krasny, 2011).

For instance, environmental problems affect them in local to global scales, so multi-scale thinking help learners to understand these complex relations (Bi et al., 2021). This skill encourage students to consider the local and global impact processes and understand sustainable processes on the environment (Milfont et al., 2012). They turn into analysts; but more importantly, they create more sustainable, more creative solutions to these complex environmental problems. The students also learn to integrate their science, engineering and math knowledge to implement their solutions to the environmental problems presented (Semerjian et al., 2004).

Discussion

There is a special relationship between environmental sustainability and STEM education in contemporary education. STEM integrates science, technology, engineering and mathematics in order to engage students in developing such skills as critical thinking, problem solving and creativity. Environmental-sustainability education also teaches students to be aware of their environment. Literature stated that integrating these two disciplines will create learning environment to enhance the students' academic and competencies as well as raising their environmental sensitivity (Enön & Hiğde, 2024; Cordaro et al., 2025). It is proven from a research that the integrated teaching of STEM education and environmental sustainability contributes to the improvement of students' academic performance as well as their ecological knowledge (Han et al., 2022). This combination of subjects assists in solving scientific and creative problems around the daily life problems the student experiences, and even develops their critical thinking, problem solving and systematic view. Moreover, environmental-centered STEM studies support individuals to gain positive attitudes related to environment and gain habits of sustainability (Ayverdi et al., 2024).

The Maker approach, blending together STEM education and sustainability and merging the do-it-yourself concept with technology, is one of the vital approaches (Sönmez & Şahinkaya, 2021). This approach allows students to come up with creative and innovative solutions while also applying their theoretical knowledge. Real-world problem-solving engages students to learn, and likely remember more of what they have learned. On the contrary, Maker spaces allow students' enhancement of skills related to technology and play a role for sustainable technologies (Demir & Güneş, 2020).

The education of STEM encourages and supports the creation of new initiatives to address environmental concerns. The use of science, interdisciplinary projects, and technology allows students to discover and analyze real-world environmental problems to brainstorm creative, tech-based solutions. Nonetheless, they have not been without their shortcomings, including an inadequate treatment of the social and cultural dimensions, a limited examination of the economic and political context, and a general neglect of local knowledge and traditional practices. Therefore, it is seen necessary to address the integration of STEM education and environmental sustainability with a more comprehensive and balanced approach (Uslu ve Boz-Yaman, 2021).

Conclusion

The connection between STEM education and environmental sustainability not only supports the academic development of students but also paves the way for positive changes in society. The STEM approach aims to provide students with skills in scientific thinking, engineering design and technology use (Beers, 2011; Hilton & Honey, 2011), while increasing environmental awareness through sustainability education. The integration of these two fields helps students learn and also makes them recognize their responsibility towards the environment. Hence better-prepared citizens are prepared for the challenges of this new and challenging times (Bybee, 2010).

STEM education has been shown to be effective and the interdisciplinary nature of STEM education creates opportunity for students to be exposed to a more complex and broad perspective on environmental issues. Students learn about environmental issues which will prepare them to act more sustainably with the help of STEM sustainability projects (Christie et al., 2015). Apart from that, these projects helps in building our critical thinking, creativity and communication skill as well as collaborating with others. It further promotes the growth of 21st century skills (Han et al., 2022). STEM-Sustainability integration is an education to serve both individual development and the good of society in a holistic way.

Since the STEM education as well as the sustainability theme provides the possibility of assessing the information of various disciplines together, it is not hard to see the connections between disciplines more clearly by students (Akarsu et al., 2020) The coupling of STEM, the sustainability topic enables the assessment of varied information from different disciplines together, and it also helps students to realize the connections between those disciplines more easily. Particularly when used with project-based learning, sustainability-driven projects allow for greater student engagement in the learning process — a win-win for students and educators! Such projects provide opportunities for students to not only gain knowledge, but also acquire experience as they apply this knowledge into real-life environmental issues (Lee & Lee, 2025). Providing enhanced learning with environmental material allows students to develop a closer relationship with their environment, potentially creating a tangible link between school and real-life experiences (Savage et al., 2008).

The future of STEM education and sustainability will continue to evolve in the next few years due to technology, education trends, and changes in our society. Considering the widespread models of data, the prevalence of digital

technologies, such as artificial intelligence, the internet of things and big data analysis, digital tools may facilitate greater integration and larger-scale consumption of this integration (Bărbulescu et al., 2025). In addition, the pertinacity of the climate crisis and environmental degradation illustrates the urgent need for education systems to transform towards sustainability. Integrating STEM education with sustainability is capable of supporting not only the academic and intellectual development of individuals, but also the achievement of long-term environmental goals by societies (Li, 2025).

Recommendations

In order to integrate STEM education and sustainability issues more effectively, it is necessary to review the national and local curricula. In this context, a structure that supports interdisciplinary perspectives and allows students to connect with real-life problems should be highlighted (Bybee, 2010; Beers, 2011; Akgündüz et al., 2015). In order for this transformation at the curriculum level to be effective, it is also important to support teachers pedagogically and to provide the infrastructure needed in practice (Altunel, 2018; Yaşar-Ekici et al., 2018). In addition, restructuring the evaluation systems in accordance with this change and re-structuring them with project-based, practice-based and process-oriented methods can be a strong step that will strengthen both the academic development of students and their environmental awareness (Toran, 2016; Bascopé ve Reiss, 2021).

Effective transfer of STEM education and sustainability to the classroom environment is possible when teachers continuously improve their knowledge and skills in these areas (Hilton & Honey, 2011). Teachers who regularly participate in professional development activities can apply both current pedagogical approaches and technology integration more effectively. Teachers from different disciplines working together on projects supports students to experience a multidimensional and holistic learning process (Yıldız et al., 2021). In this context, integrating educational technologies into the teaching process in the right way also contributes to the development of students' digital literacy skills (Christie et al., 2015). Including local environmental issues in course content places an important responsibility on teachers to increase students' environmental awareness (Huang, 2024). All these elements, together with the strengthening of teachers' professional competencies, make it possible to successfully implement an interdisciplinary and sustainability-focused STEM practice at the classroom level (Rehman et al., 2025).

Merely incorporating STEM education and sustainability into course

content is insufficient; it is crucial to infuse this approach throughout the school's operations and culture. Schools that collaborate with local communities, universities, and industry offer richer learning experiences for both students and educators (Holmlund et al., 2018). School campuses serve as dynamic learning environments where students can bridge theory and practice in sustainability. By actively participating in project planning, implementation, and evaluation, students engage in participatory learning and develop a sense of responsibility (Christie et al., 2015; Han et al., 2022). Holistic approaches not only enhance academic growth but also cultivate students' awareness of environmental issues and long-term responsibility. This nurtures individuals who can contribute to building a sustainable future (Barth & Rieckmann, 2012).

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References

- Agrawal, K., & Bhat, A. R. (2025). Advances in 3D printing with eco-friendly materials: A sustainable approach to manufacturing. *RSC Sustainability*, 3, 2582–2604. <https://doi.org/10.1039/D4SU00718B>
- Agyeman, J., & Evans, T. (2004). 'Just sustainability': the emerging discourse of environmental justice in Britain?. *The Geographical Journal*, 170(2), 155-164. <https://doi.org/10.1111/j.0016-7398.2004.00117.x>
- Akarsu, M., Okur Akçay, N., & Elmas, R. (2020). STEM Eğitimi yaklaşımının özellikleri ve değerlendirilmesi. *Bogazici University Journal of Education*, 37, 155-175.
- Akgündüz, D., Aydeniz, M., Çakmakçı, G., Çavaş, B., Çorlu, M. S., Öner, T., & Özdemir, S. (2015). *STEM eğitimi Türkiye raporu: Günün modası mı yoksa gereksinim mi?* Scala Basım. <https://doi.org/10.13140/RG.2.1.1980.0801>
- Anderson, A. (2013). Climate change education for mitigation and adaptation. *Journal of Education for Sustainable Development*, 6(2), 191–206. <https://doi.org/10.1177/0973408212475199>
- Arnold, R. D., & Wade, J. P. (2015). A definition of systems thinking: A systems approach. *Procedia Computer Science*, 44, 669-678. <https://doi.org/10.1016/j.procs.2015.03.050>
- Aşık, G., Doğança-Küçük, Z., Helvacı, B., & Corlu, M. S. (2017). Integrated teaching project: A sustainable approach to teacher education. *Turkish Journal of Education*, 6(4), 200-215. <https://doi.org/10.19128/turje.332731>
- Ayverdi, L., Börekci, C., Avcu, Y. E., Girgin, D., Özatlı, N. S., Satmaz, İ., & Yalçinkaya-Önder, E. (2024). Sürdürülebilir kalkınma amaçları bağlamında STREAM yaklaşımına yönelik öğretim tasarımlarının geliştirilmesinde fen bilimleri öğretmenlerinin görüşleri. *Dokuz Eylül Üniversitesi Buca Eğitim Fakültesi Dergisi*(62), 3005-3033. <https://doi.org/10.53444/deubefd.1482764>
- Bărbulescu, R., Enachescu, V. A., & Baltaretu, C. (2025). Integrating sustainability into STEM education through project-based learning: Empowering undergraduate students for eco-conscious innovation. In *EDULEARN25 Proceedings* (pp. 10428–10438). Palma, Spain: 17th International Conference on Education and New Learning Technologies. <https://doi.org/10.21125/edulearn.2025.2717>
- Barth, M., & Rieckmann, M. (2012). Academic staff development as a catalyst for curriculum change towards education for sustainable development: An output perspective. *Journal of Cleaner Production*, 26,

28-36. <https://doi.org/10.1016/j.jclepro.2011.12.011>

Bascopé, M., & Reiss, K. (2021). Place-based STEM education for sustainability: A path towards socioecological resilience. *Sustainability*, 13(15), 8414. <https://doi.org/10.3390/su13158414>

Beers, S. Z. (2011). *21st century skills: Preparing students for their future*. Retrived from https://www.yinghuaacademy.org/wp-content/uploads/2014/10/21st_century_skills.pdf

Bi, J., Yang, J., Liu, M., Ma, Z., & Fang, W. (2021). Toward systemic thinking in managing environmental risks. *Engineering*, 7(11), 1518-1522. <https://doi.org/10.1016/j.eng.2021.06.016>

Bryan, L. A., Moore, T. J., Johnson, C. C., & Roehrig, G. H. (2015). Integrated STEM education. In C. C. Johnson, E. E. Peters-Burton, & T. J. Moore (Eds.), *STEM road map: A framework for integrated STEM education* (pp. 23-37). Routledge. <https://doi.org/10.4324/9781315753157-5>

Bulut, S., Özkaya, A., Şahin, G., Orkun, A., Tez, B., Parladi, S. S., & Bölükbaşıoğlu, A. (2024). matematiksel modelleme ile yapılandırılmış STEM eğitiminin akıl yürütme becerisi, matematiksel yeterlik ve kaygıya etkisi. *EDUCATIONE*, 3(1), 1-32. <https://doi.org/10.58650/educatione.1367824>

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, 70, 30-35.

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. NSTA Press. <https://doi.org/10.2505/9781936959259>

Capraro, R. M., Capraro, M. M., & Morgan, J. R. (2013). *STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach* (2nd ed.). Sense Publishers. <https://doi.org/10.1007/978-94-6209-143-6>

Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., ... & Naeem, S. (2012). Biodiversity loss and its impact on humanity. *Nature*, 486, 59-67. <https://doi.org/10.1038/nature11148>

Christie, B. A., Miller, K. K., Cooke, R., & White, J. G. (2012). Environmental sustainability in higher education: How do academics teach? *Environmental Education Research*, 19(3), 385-414. <https://doi.org/10.1080/13504622.2012.698598>

Christie, B. A., Miller, K. K., Cooke, R., & White, J. G. (2015). Environmental sustainability in higher education: What do academics think? *Environmental Education Research*, 21(5), 655-686. <https://doi.org/10.1080/13504622.2013.879697>

Cole, L. B. (2023). Learnsapes for renewable energy education: An exploration of elementary student understanding of solar energy systems. *International Journal of Environmental and Science Education*, 19(1), e2305. <https://doi.org/10.29333/ijese/13034>

Cordaro, J. A., Murphy, C., & Redman, E. (2025). Bridging STEM education and sustainability: Insights from Pennsylvania educators. *Education Sciences*, 15(3), 282. <https://doi.org/10.3390/educsci15030282>

Costanza, R., Hart, M., Posner, S., & Talberth, J. (2009). Beyond GDP: The need for new measures of progress. *The Pardee Papers, No. 4*. Boston University.

Cörvers, R., Wiek, A., Kraker, J., Lang, D. J., & Martens, P. (2016). Problem-based and project-based learning for sustainable development. In: Heinrichs, H., Martens, P., Michelsen, G., & Wiek, A. (eds) *Sustainability science* (pp. 349-358). Springer, Dordrecht. https://doi.org/10.1007/978-94-017-7242-6_29

Cummings, C. M., & Cummings, T. M. (2021). Teaching non-majors hydroponics: PBL in higher education. *College Teaching*, 69(1), 1-8. <https://doi.org/10.1080/87567555.2020.1791036>

Coruhlu, T. S., & Nas, S. (2018). The impact of project-based learning environments on conceptual understanding: The “Recycling” concept. *Asia-Pacific Forum on Science Learning and Teaching*, 19(1), Article 15.

Daly, H. E. (2005). Economics in a full world. *Scientific American*, 293(3), 100-107. <https://doi.org/10.1038/scientificamerican0905-100>

Daşdemir, İ., Cengiz, E., & Aksoy, G. (2018). Türkiye’de FeTeMM (STEM) eğitimi eğilim araştırması. *Van Yüzüncü Yıl Üniversitesi Eğitim Fakültesi Dergisi*, 15(1), 1161-1183.

Demir, G., & Güneş, A. (2020). Kültürel boyutu ile “makerspace” yapılanmaları: Kütüphanelerin rolü. *NOSYON: International Journal of Society and Culture Studies*, (6), 52-71.

Demirel, Z. M., & Sungur, S. (2018). Sürdürülebilir kalkınmaya yönelik tutum ölçeğinin Türkçe’ye uyarlanması. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi*, 19(2), 1619-1633. <https://doi.org/10.29299/kefad.2018.19.02.015>

Demssie, Y. N., Biemans, H. J. A., Wesselink, R., & Mulder, M. (2023). Fostering students’ systems thinking competence for sustainability by using multiple real-world learning approaches. *Environmental Education Research*, 29(2), 261-286. <https://doi.org/10.1080/13504622.2022.2141692>

Eizenberg, E., & Jabareen, Y. (2017). Social sustainability: A new conceptual

framework. *Sustainability*, 9(1), 68. <https://doi.org/10.3390/su9010068>

English, L. D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM Education*, 3(3). <https://doi.org/10.1186/s40594-016-0036-1>

Enön, M., & Hiğde, E. (2024). STEM eğitimi ve çevre eğitimi alanında yapılan çalışmaların bibliyometrik analizi. *ADÜ Fen ve Mühendislik Bilimleri Dergisi*, 1(1), 10-18.

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., ... & Zaks, D. P. (2011). Solutions for a cultivated planet. *Nature*, 478, 337-342. <https://doi.org/10.1038/nature10452>

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The circular economy—a new sustainability paradigm?. *Journal of Cleaner Production*, 143, 757-768. <https://doi.org/10.1016/j.jclepro.2016.12.048>

Griggs, D., Stafford-Smith, M., Gaffney, Ø., Rockström, J., Öhman, M. C., Shyamsundar, P., Steffen, W., Glaser, G., Kanie, N., & Noble, I. (2013). Sustainable development goals for people and planet. *Nature*, 495, 305-307. <https://doi.org/10.1038/495305a>

Gulhan, F. (2023). The order of garden-based learning from science education to STEM education. *Eurasian Journal of Science and Environmental Education*, 3(1), 17-23. <https://doi.org/10.30935/ejsee/13040>

Gülersoy, A. E., & Civil, H. (2023). 6. sınıf Türkçe ders kitaplarının çevre eğitimi açısından incelenmesi. *Ankara Üniversitesi Çevre Bilimleri Dergisi*, 10(2), 25-42.

Gürsoy, K., Bebek, G., & Bülbül, S. (2023). The effect of STEM education practices on academic achievement and scientific process skills: A meta-analysis study. *Journal of Pedagogical Sociology and Psychology*, 5(3), 221-246. <https://doi.org/10.33902/jpsp.202324071>

Han, J., Kelley, T., & Knowles, J. G. (2022). Building a sustainable model of integrated STEM education: Investigating secondary school STEM classes after an integrated STEM project. *International Journal of Technology and Design Education*, 33, 1499-1523. <https://doi.org/10.1007/s10798-022-09777-8>

Hasanah, U. (2020). Key definitions of STEM education: Literature review. *Interdisciplinary Journal of Environmental and Science Education*, 16(3), e2217.

Hayat, H., Griffiths, T., Brennan, D., Lewis, R. P., Barclay, M., Weirman, C., Philip, B., & Searle, J. R. (2019). The state-of-the-art of sensors and

environmental monitoring technologies in buildings. *Sensors*, 19(17), 3648. <https://doi.org/10.3390/s19173648>

Hayat, M. K., Khan, T. Y., Sial, T. N., Ahmad Khan, H., Ashraf, Z. U., Sheraz, M., ... Belizaire, P. J. (2025). The biotech and precision agriculture revolution: Feeding the world sustainably. *Policy Research Journal*, 3(3), 293–316. <https://doi.org/10.5281/zenodo.15016226>

Helvaci, S. C., & Helvaci, I. (2019). An interdisciplinary environmental education approach: Determining the effects of E-STEM activity on environmental awareness. *Universal Journal of Educational Research*, 7(2), 337–346. <https://doi.org/10.13189/ujer.2019.070205>

Honey, M. A., & Hilton, M. L. (Eds.). (2011). *Learning science through computer games and simulations*. The National Academies Press.

Holmlund, T. D., Lesseig, K., & Slavitt, D. (2018). Making sense of “STEM education” in K-12 contexts. *International Journal of STEM Education*, 5(32). <https://doi.org/10.1186/s40594-018-0127-2>

Huang, C.-F. (2024). The influence of STEAM teaching activities integrating local environmental awareness on university students’ pro-environmental behavior and scientific creativity. *Journal of Baltic Science Education*, 23(6), 1193–1206. <https://doi.org/10.33225/jbse/24.23.1193>

IPCC. (2023). *Climate change 2023:synthesis report*. Intergovernmental Panel on Climate Change.

Istiana, R., Herawati, D., Herniningtyas, F., Ichsan, I. Z., & Ali, A. (2023). STEM learning to improve problem solving ability on the topic of environmental education. *Jurnal Penelitian Pendidikan IPA*, 9(3), 1202–1208. <https://doi.org/10.29303/jppipa.v9i3.2979>

Kanosvamhira, T. P. (2025). Growing together: unveiling the potential of school-based community gardens to foster well-being, empowerment, and sustainability. *Urban Transformations*, 7(2). <https://doi.org/10.1186/s42854-024-00069-z>

Karaşah-Çakıcı, Ş., Kol, Ö., & Yaman, S. (2021). The effects of STEM education on students’ academic achievement in science courses: A meta-analysis. *Journal of Theoretical Educational Sciences*, 14(2), 264–290. <https://doi.org/10.30831/akueg.810989>

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, 3(1). <https://doi.org/10.1186/s40594-016-0046-z>

Kennedy, T. J., & Odell, M. R. L. (2014). Engaging students in STEM

education. *Science Education International*, 25(3), 246–258.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, 127, 221–232.

Kök, F. (2021). Organik atıkların yönetimi, geri dönüşümü ve uygulamaları. *Ulusal Çevre Bilimleri Araştırma Dergisi*, 4(2), 99–108.

Krajcik, J. S., & Shin, N. (2014). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 275–297). Cambridge University Press.

Kricsfalussy, V., George, C., & Reed, M. G. (2018). Integrating problem-and project-based learning opportunities: Assessing outcomes of a field course in environment and sustainability. *Environmental Education Research*, 24(4), 593–610. <https://doi.org/10.1080/13504622.2016.1269874>

Lee, M. Y., & Lee, J. S. (2025). Project-based learning as a catalyst for integrated STEM education. *Education Sciences*, 15(7), 871. <https://doi.org/10.3390/educsci15070871>

Li, H. C. (2025). STEM education and sustainability: what role can mathematics education play in the era of climate change? *Research in Mathematics Education*, 27(2), 291–313. <https://doi.org/10.1080/14794802.2025.2499813>

Li, H., Huang, J., Nie, X., Chen, X., & Qin, Y. (2013). Mathematical modeling for resources and environmental systems. *Mathematical Problems in Engineering*, 2013, 674316. <https://doi.org/10.1155/2013/674316>

Malecha, E. (2020). The role of environmental education in steam education. *Hamline University Digital Commons*. Retrieved from https://digitalcommons.hamline.edu/hse_cp/463/

Milfont, T. L., Wilson, J., & Diniz, P. (2012). Time perspective and environmental engagement: A meta-analysis. *International Journal of Psychology*, 47(5), 325–334. <https://doi.org/10.1080/00207594.2011.647029>

Mulder, K. F., Segalàs, J., & Ferrer-Balas, D. (2012). How to educate engineers for/in sustainable development: Ten years of discussion, remaining challenges. *International Journal of Sustainability in Higher Education*, 13(3), 211–218. <https://doi.org/10.1108/14676371211242535>

Nguyễn, L. C., Hoa, H. Q., & Hien, L. H. P. (2025). Integrating design thinking into STEM education: Enhancing problem-solving skills of high school students. *Eurasia Journal of Mathematics, Science and Technology*

Education, 21(4), em2611. <https://doi.org/10.29333/ejmste/16084>

Nugraha, M. G., Kidman, G., & Tan, H. (2024). Interdisciplinary STEM education foundational concepts: Implementation for knowledge creation. *Eurasia Journal of Mathematics, Science and Technology Education*, 20(10), em2523. <https://doi.org/10.29333/ejmste/15471>

Oyinlola, M., Okoya, S. A., Whitehead, T., Evans, M., & Lowe, A. S. (2023). The potential of converting plastic waste to 3D printed products in Sub-Saharan Africa. *Resources, Conservation & Recycling Advances*, 17, 200129. <https://doi.org/10.1016/j.rcradv.2023.200129>

Panwar, N. L., Kaushik, S. C., & Kothari, S. (2011). Role of renewable energy sources in environmental protection: A review. *Renewable and Sustainable Energy Reviews*, 15(3), 1513–1524. <https://doi.org/10.1016/j.rser.2010.11.037>

Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: In search of conceptual origins. *Sustainability Science*, 14(3), 681–695. <https://doi.org/10.1007/s11625-018-0627-5>

Rahmadayanti, A., & Fielardh, K. (2024). Can STEM education foster students' sustainability actions? *Jurnal Pengajaran Matematika dan Ilmu Pengetahuan Alam*, 29(2). <https://doi.org/10.18269/jpmipa.v29i2.80928>

Rehman, N., Huang, X., Mahmood, A., Zafeer, H. M. I., & Mohammad, N. K. (2025). Emerging trends and effective strategies in STEM teacher professional development: A systematic review. *Humanities and Social Sciences Communications*, 12,32. <https://doi.org/10.1057/s41599-024-04272-y>

Roehrig, G. H., Dare, E. A., Ellis, J. A., & Ring-Whalen, E. (2021). Beyond the basics: A detailed conceptual framework of integrated STEM. *Disciplinary and Interdisciplinary Science Education Research*, 3, 11. <https://doi.org/10.1186/s43031-021-00041-y>

Roehrig, G., & Karişan, D. (2022). Preface to the special issue on “The why and how of integrated STEM education”. *Journal of Pedagogical Research*, 6(2), 1–3. <https://doi.org/10.33902/JPR.202211996>

Rockström, J., Steffen, W., Noone, K., vd. (2009). A safe operating space for humanity. *Nature*, 461, 472–475. <https://doi.org/10.1038/461472a>

Saari, H., Åkerman, M., Kieslinger, B., Myllyoja, J., & Sipos, R. (2021). How open is the maker movement? Integrative literature review of the openness practices in the global maker movement. *Sustainability*, 13(24), 13559. <https://doi.org/10.3390/su132413559>

Sachs, J., Schmidt-Traub, G., Kroll, C., Lafortune, G., & Fuller, G. (2019). *Sustainable development report 2019*. Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN).

Sarıkoç, Z., & Ersoy, H. (2022). Tasarım odaklı düşünme yaklaşımıyla STEM uygulamaları: SPAM eTwinning projesi örneği. *Fen Matematik Girişimcilik ve Teknoloji Eğitimi Dergisi*, 5(2), 98-122.

Savage, R. N., Chen, K. C., & Vanasupa, L. (2008). Integrating project-based learning throughout the undergraduate engineering curriculum. *Journal of STEM Education: Innovations and Research*, 8(3). Retrieved from <https://jstem.org/jstem/index.php/JSTEM/article/view/1387>

Semerjian, L., El-Fadel, M., Zurayk, R., & Nuwayhid, I. (2004). Interdisciplinary approach to environmental education. *Journal of Professional Issues in Engineering Education and Practice*, 130(3). [https://doi.org/10.1061/\(ASCE\)1052-3928\(2004\)130:3\(173\)](https://doi.org/10.1061/(ASCE)1052-3928(2004)130:3(173))

Shamuganathan, S. (2023). STEM project-based learning activities for sustainability: Enhancing scientific and 21st-century skills among pre-university students. *Learning Science and Mathematics*, 18, 62-83.

Sönmez, S., & Şahinkayası, Y. (2021). Öğretmenlerin maker hareketi ve robotik kodlama faaliyetlerinde yaşadığı sorunlar ve önerileri. *Mustafa Kemal Üniversitesi Eğitim Fakültesi Dergisi*, 5(7), 277-296.

Stave, K. A., & Hopper, M. (2007). What constitutes systems thinking? A proposed taxonomy. In *Proceedings of the 25th International Conference of the System Dynamics Society* (pp. 1–15). Boston, MA: System Dynamics Society.

Suherman, S., Vidákovich, T., Mujib, M., Hidayatulloh, H., Andari, T., & Susanti, V. D. (2025). The role of STEM teaching in education: An empirical study to enhance creativity and computational thinking. *Journal of Intelligence*, 13(7), 88. <https://doi.org/10.3390/jintelligence13070088>

Toran, M. (2016). Sürdürülebilir anaokulları: Okul öncesi eğitim kurumlarının değerlendirilmesi. *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi*, 16(3), 1035-1046.

UNESCO. (2017). *Education for sustainable development goals: learning objectives*. Paris, UNESCO.

UNESCO. (2021). *Engineering for sustainable development: Delivering on the sustainable development goals*. UNESCO Publishing.

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development*. United Nations.

United Nations (UN). (2022). *The sustainable development goals report 2022*. United Nations.

Uslu, S., & Boz-Yaman, B. (2021). STEM temelli çevreci sifon etkinliği uygulamasından yansımalar. *Pamukkale Üniversitesi Eğitim Fakültesi Dergisi* (53), 457-494. <https://doi.org/10.9779/pauefd.787908>

Ürge-Vorsatz, D., Herrero, S., Dubash, N. K., & Lecocq, F. (2014). Measuring the co-benefits of climate change mitigation. *Annual Review of Environment and Resources*, 39, 549-582. <https://doi.org/10.1146/annurev-environ-031312-125456>

Vallance, S., Perkins, H. C., & Dixon, J. E. (2011). What is social sustainability? A clarification of concepts. *Geoforum*, 42(3), 342-348. <https://doi.org/10.1016/j.geoforum.2011.01.002>

Vijayatheepan, R. (2023). Investigating the relationship between science literacy and environmental safety among citizens. ResearchGate. https://www.researchgate.net/publication/376522695_Investigating_the_Relationship_between_Science_Literacy_and_Environmental_Safety_among_Citizens

Vyas, D., Khan, A.H., & Cooper, A. (2023). Democratizing making: Scaffolding participation using e-waste to engage under-resourced communities in technology design. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, 301, 1-16. <https://doi.org/10.1145/3544548.3580759>

Warszawski, L., Kriegler, E., Lenton, T. M., Gaffney, O., Jacob, D., Klingensfeld, D., ... Rockström, J. (2021). All options, not silver bullets, needed to limit global warming to 1.5 °C: A scenario appraisal. *Environmental Research Letters*, 16(6), 064037. <https://doi.org/10.1088/1748-9326/abfeec>

Williams, A., Kennedy, S., Philipp, F., & Whiteman, G. (2017). Systems thinking: A review of sustainability management research. *Journal of Cleaner Production*, 148, 866-881. <https://doi.org/10.1016/j.jclepro.2017.02.002>

Woern, A. L., McCaslin, J. R., Pringle, A. M., & Pearce, J. M. (2018). RepRapable Recyclebot: Open source 3-D printable filament extruder. *HardwareX*, 4, e00026. <https://doi.org/10.1016/j.ohx.2018.e00026>

Wu, X., Yang, Y., Zhou, X., Xia, Y., & Liao, H. (2024). A meta-analysis of interdisciplinary teaching abilities among elementary and secondary school STEM teachers. *International Journal of STEM Education*, 11, 38. <https://doi.org/10.1186/s40594-024-00500-8>

Xie, Y., Fang, M., & Shauman, K. (2015). STEM education. *Annual*

Review of Sociology, 41, 331-357. <https://doi.org/10.1146/annurev-soc-071312-145659>

Yaşar-Ekici, F., Bardak, M., & Yousef-Zadeh, M. (2018). Erken çocukluk döneminde STEM. In A. Kırkıç & E. Aydın (Eds.), *Merhaba STEM yenilikçi bir öğretim yaklaşımı* (s. 51-78). Eğitim Yayınevi.

Yıldırım, B., & Altun, Y. (2015). STEM eğitim ve mühendislik uygulamalarının fen bilgisi laboratuvar dersindeki etkilerinin incelenmesi. *ECJSE*, 2(2), 28-40. <https://doi.org/10.31202/ecjse.67132>

Yıldız, K., Güzel-Gürbüz, P., Esentaş, M., Beşikci, T., & Balıkçı, İ. (2021). Üniversite öğrencilerinin sürdürülebilir çevre eğitimi ve çevre sorunlarına yönelik tutumları arasındaki ilişkinin incelenmesi. *International Journal of Social Science Research*, 10(1), 35-49.

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