



# STEAM in SDGs

Encouraging Students To Enhance Their  
STEAM Skills In Order To Address  
Real-World SDG-Related Challenges

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# STEAMinSDGs GUIDEBOOK



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## Abstract

The document serves as a guidebook for integrating the Sustainable Development Goals (SDGs) into the multidisciplinary realm of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. It examines crucial facets, such as providing an overview of both SDGs and the landscape of STEAM education, explaining the links between SDGs and STEAM, and investigating motivational drivers within STEAM education. It explores effective teaching methodologies and best practices, with a focus on integrating active citizenship principles and SDGs into STEAM education. Additionally, the document showcases existing models and initiatives that combine citizenship education with STEAM, offering valuable insights into successful teaching approaches. Furthermore, it addresses the challenges encountered in integrating SDGs into STEAM education, offering practical solutions to overcome potential barriers.

Authors and Editors: STEAMinSDGs partners



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## Introduction

### The STEAMinSDGs project and its objectives

The STEAMinSDGs project draws its inspiration from two primary pillars: Education for SDGs and STEAM Education.

**Education for SDGs:** It emphasizes the importance of integrating the 17 Sustainable Development Goals (SDGs) into educational curricula. The project aims to address these issues to effectively promote understanding and action on SDGs among students.

**STEAM Education:** Recognizing the significance of STEAM (Science, Technology, Engineering, Arts, Mathematics) education for future employability, the project seeks to equip students with essential skills and knowledge. It also seeks to bridge performance gaps among students in the EU and the gender gap in STEAM performance. The project advocates for encouraging more girls to pursue STEAM careers.

By combining STEAM education with SDG education, STEAMinSDGs aims to provide teachers with resources to attract, support, and inspire students, especially low-performing students including girls, to raise their awareness and understanding of the SDGs and their connection to STEAM disciplines, thereby fostering their skills and interest in both fields and encouraging them to become active and responsible citizens.

### Integrating SDGs into STEAM Classes

In the ever-evolving landscape of education, there exists a growing imperative to equip students with not only academic knowledge but also the skills and mindset necessary to navigate the complexities of our world. Central to this goal is the integration of Sustainable Development Goals (SDGs) into the curriculum, particularly within the framework of Science, Technology, Engineering, Arts, and Mathematics (STEAM) classes. STEAM has been an improved and softer version of STEM which did not include Arts thus being more scientific in form. Arts, on the other hand, gave way to more descriptive and synthetic approach and smartly combines calculative and hard subjects with creative and visual art, history, languages, reading and writing. This integration represents a forward-looking approach that recognizes the critical role of education in fostering active citizenship, global awareness, and a commitment to sustainable development.

STEAM education, with its interdisciplinary nature and emphasis on innovation and problem-solving, provides an ideal platform for addressing the multifaceted challenges outlined in the SDGs. By infusing SDGs into STEAM classes, educators can leverage the inherent creativity, curiosity, and analytical skills of students to explore real-world issues and develop meaningful solutions. This introduction sets the stage for a deeper exploration of how integrating SDGs into STEAM classes not only enriches academic



learning but also cultivates a sense of social responsibility and empowers students to become agents of positive change in their communities and beyond.

Implementing Sustainable Development Goals into STEAM classes may seem too invasive into the lesson structure but it certainly is not the case as most goals are inherently connected with school curriculum at any educational stage. Still, it is vital for the teachers to stress the importance of SDGs goals which only too often may pass by unnoticed during the classroom activities. While both teachers and students go carefully through all the 17 goals, analyze them, and visualize the importance of them being implemented into the education process, it will become a habit to spot and highlight any of the goals that appear in the course of the lesson.

### **Guidebook Objective:**

The objective of this document is to explore strategies and approaches for teachers to effectively integrate Sustainable Development Goals (SDGs) into Science, Technology, Engineering, Arts, and Mathematics (STEAM) classes. The focus is on identifying methods that help teachers motivate students towards active citizenship while simultaneously fostering interest and engagement in STEAM fields.

# Overview of SDGs and STEAM Education

## A brief overview of the Sustainable Development Goals (SDGs)

### The Sustainable Development Agenda

#### 17 Goals for People, for Planet

World leaders came together in 2015 and made a historic promise to secure the rights and well-being of everyone on a healthy, thriving planet when they adopted the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs).

The Agenda remains the world’s roadmap for ending poverty, protecting the planet and tackling inequalities. The 17 SDGs, the cornerstone of the Agenda, offer the most practical and effective pathway to tackle the causes of violent conflict, human rights abuses, climate change and environmental degradation and aim to ensure that no one will be left behind. The SDGs reflect an understanding that sustainable development everywhere must integrate economic growth, social well-being and environmental protection. (United Nations, 2023)



Source : <https://frigiv.palsgaard.com/media/1303/palsgaard-supports-the-un-sustainable-development-goals.jpg>

Goal	Explanation
Goal 1	End poverty in all its forms everywhere
Goal 2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
Goal 3	Ensure healthy lives and promote well-being for all at all ages
Goal 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5	Achieve gender equality and empower all women and girls
Goal 6	Ensure availability and sustainable management of water and sanitation for all
Goal 7	Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10	Reduce inequality within and among countries
Goal 11	Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12	Ensure sustainable consumption and production patterns
Goal 13	Take urgent action to combat climate change and its impacts
Goal 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17	Strengthen the means of implementation and revitalize the global partnership for sustainable development (United Nations, n.d.)

#### Further reading:

- The Sustainable Development Goals Report 2023: Special Edition (<https://unstats.un.org/sdgs/report/2023/>)
- SDGs – Fast Facts (<https://www.un.org/sustainabledevelopment/sdg-fast-facts/>)

#### Watch on Youtube:

- Sustainable Development Goals - EXPLAINED in 5 minutes! ([https://www.youtube.com/watch?v=RmCH\\_-xHT8](https://www.youtube.com/watch?v=RmCH_-xHT8))



## The status and trends of STEAM education

STEAM education refers to an interdisciplinary approach to learning that incorporates Science, Technology, Engineering, Arts, and Mathematics into the curriculum. The motive of this program is to provide students with a well-rounded education that allows them to develop critical thinking, problem solving, creativity, and innovation skills.

It helps to foster an interest in science and technology, as well as encourage creativity and innovation. It also prepares children for careers in a rapidly changing world where technology constantly evolves.

Some popular trends in STEAM education are shown below:

### Virtual Reality and Augmented Reality

The use of VR and AR technology can enhance STEAM education through the following ways:

- **Immersive Learning:** VR and AR create a highly immersive learning experience that allows students to explore and interact with 3D models and simulations of complex concepts. This approach can help students gain a deeper understanding of STEAM topics.
- **Visualizations and Simulations:** VR and AR can create visualizations and simulations that are difficult or impossible to replicate in real life, allowing students to explore abstract concepts in a safe and controlled environment.
- **Increased Engagement:** VR and AR can make STEAM education more engaging by providing interactive and engaging experiences that make learning fun.
- **Personalized Learning:** VR and AR can be customized to students' individual needs and learning styles, allowing them to learn at their own pace and in their way.
- **Collaboration:** VR and AR can facilitate collaboration among students, allowing them to work together in virtual environments and share ideas.
- **Accessibility:** VR and AR can make STEAM learning more accessible to students with disabilities, allowing them to explore concepts and topics that may be difficult to experience in real life.

### Robotics and Artificial Intelligence

Using robotics and AI in STEAM learning offers numerous benefits for children, including:

- **Enhancing problem-solving skills:** Robotics and AI encourage children to think critically and solve problems creatively and innovatively. They provide a practical and hands-on approach to learning, which is essential for developing problem-solving skills.

- **Improving coding skills:** Robotics and AI use programming languages such as Python, Scratch, and Arduino, which help children develop coding skills. These skills are important for the future as technology continues to advance.
- **Encouraging teamwork and collaboration:** Robotics and AI involve teamwork and collaboration, which are essential skills in the workplace. Children learn to work in teams and collaborate to achieve common goals.
- **Stimulating creativity:** Robotics and AI provide a creative outlet for children to express themselves. They can design, build, and program robots, which allows them to explore their creativity and imagination.
- **Enhancing spatial awareness:** Robotics and AI involve designing and building physical objects, which enhances children's spatial awareness and develops their spatial reasoning skills.
- **Preparing children for the future:** Integrating robotics and AI in STEAM learning prepares children for the future job market, requiring a deep understanding of technology.

### Project-Based Learning

The advantages of Project-Based Learning in STEAM Education:

- **Engages students:** PBL promotes active, hands-on learning and engages students in the learning process, making it more meaningful and relevant to them.
- **Develops STEAM skills:** PBL provides opportunities for students to apply and develop their skills in science, technology, engineering, art, and math (STEAM).
- **Promotes collaboration:** PBL requires students to work collaboratively in teams, helping them develop communication, leadership, and teamwork skills.
- **Encourages creativity and innovation:** PBL encourages students to think creatively and develop innovative solutions to real-world problems or challenges.
- **Fosters inquiry-based learning:** PBL promotes inquiry-based learning, where students ask questions, investigate, and analyze information, promoting curiosity and lifelong learning.

### Interdisciplinary Learning

Interdisciplinary learning refers to connecting and integrating knowledge and skills from multiple academic disciplines or subject areas. It involves synthesizing ideas, concepts, and practices from different fields to solve complex problems, answer real-world questions, and fully understand a topic. (Codingal, n.d.)

## Existing connections between SDGs and STEAM education

Sustainable Development Goals (SDGs) and STEAM education (Science, Technology, Engineering, Arts, and Mathematics) are interconnected in various ways, as both aim to address global challenges and promote a sustainable and inclusive future. Here are some of the key connections between SDGs and STEAM education:

- 1. Problem Solving and Innovation (SDG 9, SDG 4):**
  - a. SDG 9 (Industry, Innovation, and Infrastructure): STEAM education fosters critical thinking and problem-solving skills, essential for innovation and sustainable development.
  - b. SDG 4 (Quality Education): STEAM education provides the foundation for developing the skills needed to create innovative solutions to global challenges.
- 2. Clean Energy and Environmental Sustainability (SDG 7, SDG 13, SDG 14, SDG 15):**
  - a. SDG 7 (Affordable and Clean Energy): STEAM disciplines contribute to the development of clean energy technologies.
  - b. SDG 13 (Climate Action): STEAM education equips individuals with the knowledge and skills to address climate change through sustainable practices and innovations.
- 3. Health and Well-being (SDG 3):**
  - a. STEAM fields play a crucial role in medical research, healthcare technology, and the development of solutions for health challenges, aligning with SDG 3's focus on good health and well-being.
- 4. Education and Lifelong Learning (SDG 4):**
  - a. STEAM education is fundamental to achieving SDG 4, which emphasizes inclusive and equitable quality education and lifelong learning opportunities for all.
- 5. Gender Equality (SDG 5):**
  - a. Promoting STEM and STEAM education can help address gender disparities in these fields, contributing to SDG 5's goal of achieving gender equality and empowering all women and girls.
- 6. Inclusive Innovation and Infrastructure (SDG 9, SDG 11):**
  - a. STEAM education supports the development of inclusive and sustainable infrastructure, aligning with SDG 9, and contributes to the creation of sustainable cities and communities (SDG 11).
- 7. Partnerships for the Goals (SDG 17):**
  - a. Collaboration between educational institutions, governments, businesses, and communities is essential for achieving both SDGs and advancing STEAM education.
- 8. Cultural Understanding and Creativity (SDG 4, SDG 16):**
  - a. The inclusion of the arts in STEAM fosters creativity and cultural understanding, contributing to SDG 4's goal of promoting quality education and SDG 16's goal of promoting just, peaceful, and inclusive societies.

Within this framework, Sustainable Development Goals (SDGs) are interconnected in STEAM education subjects highlighting the integral role of STEAM education in advancing sustainable development and fostering a culture of innovation, creativity, and global citizenship among learners.

	<p>Languages – readings promoting the topic, Art – posters on the subject, Social Studies – explaining economic conditions, overall school activities - charity actions</p>
	<p>Languages – readings promoting the topic, Biology – food production, Art – posters on the topic, Social Studies – explaining economic conditions, Geography – hunger prone regions, Food technology – food saving, overall school activities - charity actions</p>
	<p>Biology – healthy lifestyle, Physical Education, Sports – being fit, Food technology – balanced diet, overall school activities – promoting health and fitness</p>
	<p>Languages - readings promoting the topic, History - explaining past conditions concerning education, Art – posters promoting the subject, overall school activities – promoting importance of education</p>
	<p>Maths and Engineering – promoting female role models in “male” subjects, explaining past conditions concerning inequality of sexes, Art – posters, languages – readings promoting sex equality, Physical Education, Sports – teachings and readings promoting equality of all people</p>
	<p>Languages – readings promoting the topic, Biology – water circle in ecosystem, Art – posters on the topic, Social Studies – explaining economic conditions, Geography – water scarcity prone regions, Food technology – water saving, overall school activities - charity actions</p>
<p>Biology – renewable energy sources, saving environment, Engineering – constructions of RES models, Languages – readings promoting the topic,</p>	

	<p>Technology – information about RES</p>
	<p>Social Studies – explaining economic conditions, History – explaining past conditions concerning economics; Job Counselling – tests, information, work market, overall school activities –attending job fairs</p>
	<p>Maths and Engineering – promoting technical subject and employment in these sectors, Technology – promoting innovative solutions, Art – posters, Languages – readings promoting the subject</p>
	<p>Geography – differences and inequalities among countries of the world, History – explaining past conditions leading to inequalities, Languages – readings promoting the topic, overall school activities - charity actions promoting UNICEF actions</p>
	<p>Biology – plants and their function in cities and towns, Art – nature in paintings, History – industrialisation and nature, overall school activities - public gardening, vertical gardens in urban areas</p>
	<p>Food Technology – sustainable agriculture, Technology – fashion, Biology – responsible farming and harvesting, Physical Education, Sports – diets and health, Languages – readings promoting the topic</p>
	<p>Science and Biology - climate change, exploring its causes and effects on ecosystems; Geography - focus on regions most affected by climate change and discuss mitigation strategies; Technology - renewable energy and sustainable practices; Art - climate change and its impact on the environment, Languages - literature and articles promoting awareness and action on climate change</p>
<p>Biology - marine ecosystems, biodiversity;</p>	

	<p>Geography - explore the impact of human activities on oceans and marine habitats, including pollution and overfishing;          Art - artwork depicting underwater scenes and the beauty of marine life;          Languages - literature and articles promoting conservation efforts for marine environments;          Overall school activities - beach clean-ups and educational campaigns to protect life below water.</p>
	<p>Biology and Science– ecosystems in our times, climate change and its long-term consequences,          Languages – readings promoting flora and fauna of the world,          History – past reflections on the topic,          Art – visual concepts of nature, posters,          overall school activities – promoting socially acceptable actions promoting fighting climate changes</p>
	<p>Social Studies – constitutional rights, citizens’ rights,          History – war and peace as a part of human lifestyle,          Languages – readings promoting the topic,          Art – posters,          overall school activities – promoting trust in legal institutions of the country,</p>
	<p>All subjects, extracurricular projects like e-Twinning and Erasmus+</p>

STEAM education is a key enabler for achieving various Sustainable Development Goals by equipping individuals with the skills and knowledge needed to address global challenges and contribute to a more sustainable and inclusive world. Integrating STEAM education into curriculum and promoting interdisciplinary approaches can help build a generation of problem solvers and innovators committed to sustainable development.

## Motivational Factors in STEAM Education

The integration of STEAM subjects is vital for equipping students with the necessary skills for the 21st century. Engaging students in these subjects can be challenging, necessitating an understanding of motivational factors that drive interest and engagement (Beers, 2016).

### Literature Review on Motivational Factors in STEAM

Understanding the motivational factors that encourage students to engage with STEAM subjects is essential for developing effective educational strategies. This section highlights the complexities of student motivation in the context of STEAM education and offers a more nuanced view of the underlying principles that drive student interest and engagement.

Deci and Ryan's Self-Determination Theory (SDT) suggests that motivation is multifaceted, consisting of intrinsic and extrinsic types. Intrinsic motivation, where students engage in learning for its own sake, is particularly crucial in the context of STEAM education. Students are more likely to develop a lasting interest in STEAM subjects when they find the activities inherently satisfying and enjoyable (Deci & Ryan, 2000). Conversely, extrinsic motivation involves engaging in an activity to achieve some separate outcome, such as rewards or grades. While extrinsic motivators can be effective in the short term, they may not foster a deep, enduring passion for STEAM subjects.

The literature also emphasizes the importance of relevance and context in motivating students. Fortus et al. (2004) argue that connecting STEAM learning to real-world problems and applications can significantly enhance student interest and motivation. This approach not only makes learning more meaningful but also helps students understand the practical value of their knowledge and skills.

Moreover, the role of autonomy in student motivation cannot be overstated. When students are given the freedom to explore topics of personal interest within the STEAM curriculum, they are more likely to be intrinsically motivated. According to Stefanou, Perencevich, DiCintio, and Turner (2004), providing students with choices in their learning processes fosters a sense of ownership and control, which in turn enhances engagement and motivation.

Collaborative learning environments also play a crucial role in motivating students. When students work together on projects, they benefit from peer learning and the social construction of knowledge. This collaboration can lead to increased motivation and engagement by providing a sense of belonging and community within the classroom (Johnson & Johnson, 2009).

Another critical factor in STEAM motivation is the challenge and success cycle. Appropriate levels of challenge can stimulate student interest and engagement. However, it's important that these challenges are achievable to avoid frustration. Bandura (1997) highlights the importance of self-efficacy in this context, noting that students who believe in their ability to succeed in challenging tasks are more likely to be motivated and persist in their efforts.

Finally, the integration of the Arts into STEM education has been shown to enhance motivation by incorporating creativity and self-expression into the learning process. Root-Bernstein et al. (1999) argue that this integration not only makes learning more enjoyable but also helps develop innovative thinking skills, which are crucial in all STEAM fields.

## Key factors that contribute to student engagement in STEAM

- **Real-World Relevance:** tying STEAM subjects to real-world scenarios enhances student interest. Fortus, Dershimer, Krajcik, Marx, and Mamlok-Naaman (2004) argue that relevance to everyday life can significantly increase student motivation to learn.
- **Hands-on learning:** project-based learning is essential in STEAM education, as it allows students to engage in exploration and problem-solving. Capraro and Morgan (2013) found that hands-on, project-based learning experiences lead to higher student engagement and understanding.
- **Encouragement and support:** positive reinforcement from teachers is vital for student motivation. Hidi and Harackiewicz (2000) suggest that encouragement and interest from teachers and peers can enhance students' intrinsic motivation.
- **Incorporating arts:** the inclusion of arts in STEM education introduces creativity, making learning more appealing. Root-Bernstein et al. (1999) discuss how integrating arts into STEM subjects fosters innovation and critical thinking.

## Successful strategies used by teachers to motivate students

- **Interdisciplinary projects:** Honey, Pearson, and Schweingruber (2014) advocate for the integration of STEAM with other subjects, such as social studies, to create more comprehensive learning experiences.
- **Technology integration:** Papert and Harel (1991) emphasize the role of technology in making learning more interactive and engaging, suggesting that tools like coding software can make STEAM subjects more accessible.
- **Teamwork and collaboration:** Johnson and Johnson (2009) highlight the importance of collaborative learning, noting that teamwork can improve problem-solving skills and motivation.
- **Professional engagement:** exposure to professionals from STEAM fields can inspire students. By bringing in experts to discuss their work, students gain insight into real-world applications of their studies (Falk and Dierking, 2010).

Motivating students in STEAM requires a comprehensive approach that includes real-world relevance, hands-on learning, positive reinforcement, and the integration of arts. Strategies such as





interdisciplinary projects, technology use, collaborative learning, and professional engagement can significantly impact student motivation and engagement (Sanders, 2009). The continued exploration and implementation of these strategies are essential for enhancing STEAM education in primary schools.

## Active Citizenship in Education

Active citizenship in education refers to the integration of civic engagement and social responsibility into the educational experience of students. It emphasizes teaching young people not only academic subjects but also the knowledge, skills, and attitudes necessary for informed and responsible participation in society (Liu et. al, 2021).

### The concept of active citizenship in educational settings

According to UNESCO glossary, if we search for active citizenship definition, we find only explanation of global citizenship and education for sustainable development. So, if we search for an answer how to create opportunity for become an active citizen we have to choose education for sustainable development definition where is stated that EDS empowers learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations, while respecting cultural diversity. It is about lifelong learning and is an integral part of quality education.

Morrissey & Heidkamp (2022) recognize the importance and advantages of community engagement and empowerment, especially in educational institutions. ESD, also known as Education for Global Citizenship (EGC), is no longer just a set of educational activities, but a necessity that needs to find a place in curricula, pedagogy, classrooms, educational institutions, and society at large. Wals & Lenglet (2016) point out that ESD is a form of education that aims to create “sustainability citizens”.

Research by Menzie-Ballantyne & Ham (2022) suggests that an integrated approach using ESD and EGC pedagogy has the potential to:

1. enhance the development of literacy and numeracy;
2. hold potential for easing the pressures of a crowded curriculum;
3. provide students the opportunity to engage with their communities on real-world issues;

hold the key to fostering the knowledge, skills, values, attitudes, and actions needed for employment and effective citizenship in a globalized world.

To assess the situation in OECD countries, the International Civic and Citizenship Education Study in the third cycle of ICCS (2022) was set out to address aspects related to global citizenship, sustainable development, migration, changes to traditional political systems, and the use of digital technologies for civic engagement, which shows how important it is to explore students as active citizenship agents.

Each focus area was developed in response to recent developments that were viewed as relevant to the area of civic and citizenship education in the 21st century.

While not always established as a specific subject area, civic and citizenship education tends to be included across national curricula as a learning area that seeks to support young people’s knowledge

and understanding of society's principles and institutions, their critical appraisal of citizens' roles and responsibilities, and their learning on how to influence policies and practices through democratic processes (Ainley et al., 2013; European Commission/EACEA [European Education and Culture Executive Agency]/Eurydice, 2017).

There is ample evidence of the diversity in how civic and citizenship education is implemented across different education systems, with often overlapping approaches that range from the teaching of specific civic-related subjects through to its integration into other related subjects (such as history or social science studies), to its definition as a cross-curricular learning area (Council of Europe, 2018; Malak-Minkiewicz & Torney-Purta, 2021). Nevertheless, there is a broad consensus about the importance of preparing young people for citizenship as part of school education (European Commission/EACEA/Eurydice, 2017). Traditionally, the acquisition of knowledge about civic institutions, decision-making processes, and citizenship rights and responsibilities have been at the core of civic learning (Geboers et al., 2013). Recently, the notion of providing young people at school with opportunities to engage and experience ways of engaging in society has become more prominent in curricular approaches across many countries (Barber et al., 2015). Some of these approaches are related to the concept of creating a "whole school" environment that promotes participation and non-formal civic learning through experience among students at school.

While there has been a dominant focus on the nation state as the point of reference for civic learning, globalization, digitalization, and increased levels of migration have led to interest in the notion of global citizenship as a concept of being members of a globalized community (Oxley & Morris, 2013). This includes the idea of multiple identities such as being national, regional, and/or global citizens (European Commission/EACEA/Eurydice, 2017; UNESCO [United Nations Educational, Scientific and Cultural Organization], 2015). Further, the concept of education for sustainable development (ESD) has emerged in response to increasing concerns about global threats to the environment and the sustainability of the socio-demographic and economic development of mankind. ESD is sometimes defined as conceptually overlapping with and sometimes as separate from the concept of global citizenship education (GCED) (Chung & Park, 2016; Kopnina & Meijers, 2014).

## Empowering Active Citizenship through SDGs in STEAM Education

Guiding the principles of sustainable development, the Sustainable Development Goals (SDGs) provide an orientation for the complex and global challenges facing humanity in the 21st century. The equally diverse references to STEAM subjects (Science, Technology, Engineering, Arts, Mathematics) in the SDGs suggest the need for the expertise of people from STEAM disciplines to meet these challenges (Wiegand, Ferri, 2023)

The concepts of ESD and the 2030 Learning Compass are of great importance because of the unpredictability of the future society and environment, particularly technological advances that may cause drastic changes in the global economy, society, and environment in the near future. The ability of social citizens nurtured under the current education system to effectively adapt to and cope with these changes will profoundly affect how countries and society develop in the future. Based on the

above, in recent years, competency-based teaching has received considerable attention; competency refers to one's ability to appropriately apply his or her knowledge, skills, attitudes, and values in daily life. STEM/STEAM (science, technology, engineering, art, and mathematics) education, a form of interdisciplinary education, is a way to successfully implement competency-based teaching (Wang, Lim, Lavonen, and Clark-Wilson, 2019). STEM/STEAM education facilitates meaningful learning for students by promoting the interdisciplinary integration of knowledge and skills among the STEAM fields. One of the goals of STEM/STEAM education is to foster the STEM/STEAM skills of students, enhancing their employability, their ability to solve complex industry problems, and their capacity to better the lives of all beings on Earth (White House, 2018). STEM/STEAM education has now received attention from educational institutions, parents, society, and industries, and many countries—seeing STEM/STEAM education as a crucial education model for boosting national competitiveness and talent cultivation—have been formulating policies relevant to the education. Nonetheless, Bybee (2013) indicated the need for further investigation into the various aspects of STEM/STEAM education to ensure its efficacy and values.

There is new issue called Aspirations within Interdisciplinary STEM/STEAM Education under the Education for Sustainable Development (ESD), which includes researches on EDS and STEAM to explore more.

## Existing models or programs that integrate citizenship education with STEAM

Several existing models and programs integrate citizenship education with STEAM (Science, Technology, Engineering, Arts, and Mathematics), fostering the development of active and responsible citizens. Some of them are:

**European Citizen Science Association (ECSA):** ECSA promotes citizen science projects across Europe that engage citizens in scientific research. These projects often involve collaboration between scientists and volunteers, integrating STEAM principles with civic engagement and scientific inquiry. [website: <https://www.ecsa.ngo/>]

**Erasmus+ Programme:** Within the Erasmus+ framework, there are various projects and partnerships focused on sustainability education that incorporate STEAM elements. These initiatives aim to enhance environmental literacy, promote sustainable development, and empower citizens to take action on climate change and other pressing issues. [website: <https://erasmus-plus.ec.europa.eu/>]

**European Coding Initiative (EU Code Week):** EU Code Week promotes digital literacy and coding skills among European citizens of all ages. By integrating coding and computational thinking into educational curricula, EU Code Week fosters digital citizenship and empowers individuals to participate actively in the digital economy and society. [website: <https://codeweek.eu/>]

**European Heritage Days (EHD):** EHD celebrates Europe's cultural heritage through events, activities, and educational initiatives. These programs often integrate arts education with citizenship themes,

fostering appreciation for cultural diversity, heritage preservation, and civic engagement. [website: <https://www.europeanheritagedays.com/>]

**European Schoolnet (EUN):** EUN supports the development and implementation of STEM (Science, Technology, Engineering, and Mathematics) education initiatives across Europe. Through projects like Scientix and STE(A)M IT, EUN promotes interdisciplinary learning, inquiry-based approaches, and civic engagement in STEM education. [website: <https://www.europeanschoolnetacademy.eu/>]

**Global Education Network Europe (GENE):** GENE promotes global citizenship education (GCE) in European schools through partnerships, training programs, and resource development. GENE projects often integrate STEAM subjects with global issues, fostering critical thinking, cultural awareness, and civic action among students. [website: <https://www.gene.eu/>]

**European Innovation Academy (EIA):** EIA offers entrepreneurship education programs that encourage students to develop innovative solutions to societal challenges. By combining STEAM skills with entrepreneurial mindset training, EIA empowers students to become active agents of change and contribute to economic and social development. [website: <https://www.inacademy.eu/>]

These examples demonstrate the diverse range of models and programs in Europe that integrate citizenship education with STEAM. By combining academic learning with real-world applications, interdisciplinary approaches, and civic engagement opportunities, these initiatives prepare European citizens to address complex challenges and contribute to sustainable development in their communities and beyond.

## Teaching Strategies and Best Practices

The integration of Sustainable Development Goals (SDGs) into STEAM classes represents a dynamic and impactful approach to education. To assist educators in this integration, the following strategies and practices have been recognized as both effective and innovative.

### Effective Teaching Strategies for Integrating SDGs into STEAM Classes

Educators aiming to incorporate Sustainable Development Goals (SDGs) into their STEAM curriculum can leverage a variety of effective teaching strategies to create meaningful learning experiences.

**Contextualization:** Placing STEAM concepts within the context of SDGs can dramatically increase their relevance. For example, when teaching about renewable energy in physics, students can evaluate local renewable energy usage against global trends, linking to SDG 7: Affordable and Clean Energy.

**Problem-Based Learning (PBL):** Project-Based Learning (PBL) is a cornerstone strategy for embedding SDGs within STEAM. Through PBL, educators can create opportunities for students to work on real-world problems directly related to specific SDGs (Bell, 2010). It's highly effective for integrating SDGs into STEAM as it mirrors the complexity and interdisciplinary nature of real-world issues. A PBL task might involve students in creating sustainable urban transport models, which aligns with SDG 11: Sustainable Cities and Communities, combining engineering, environmental science, and technology.

**Collaborative Projects:** Encourage collaboration among students to solve problems related to SDGs. For instance, students could work together to design a water filtration system, addressing SDG 6: Clean Water and Sanitation. Collaborative projects help students learn teamwork and negotiation skills essential for addressing global challenges.

**Inquiry-Based Science Education (IBSE):** IBSE promotes the learning of science through inquiry, often triggered by a question or a problem posed to the learners. Students might investigate the effects of climate change on local ecosystems, engaging with SDG 13: Climate Action. This strategy encourages students to become active learners, questioning, exploring, and assessing what they know.

**Integration of Technology:** Digital tools and simulations can bring SDGs to life within STEAM subjects. Using software to simulate the impact of various materials on the carbon footprint of a building can provide insights into SDG 12: Responsible Consumption and Production.

### Innovative and/or Successful Approaches Used by Educators

Educators across the globe have been creatively incorporating SDGs into STEAM education through various innovative and successful approaches.

**Gamification:** Implementing game-based learning can make the exploration of SDGs more engaging. Teachers can use gamification to transform complex problems into interactive challenges that encourage students to apply STEAM concepts in a competitive and fun way. For example, a classroom could engage in a game that simulates the management of a city’s resources, challenging students to apply sustainable practices in line with SDG 11: Sustainable Cities and Communities.

**Technology-Enhanced Learning:** The use of virtual reality (VR) and augmented reality (AR) offers students immersive experiences to explore the impact of human activities on ecosystems, aligning with SDGs such as SDG 14: Life Below Water and SDG 15: Life on Land. Through VR field trips, students can witness the bleaching of coral reefs or deforestation, fostering empathy and a deeper understanding of environmental issues.

**Flipped Classrooms:** FC have revolutionized traditional teaching methodologies, particularly within STEAM education, by assigning research and discovery outside of the classroom (Bergmann & Sams, 2012). This approach promotes independent learning and encourages students to engage deeply with SDG-related content before participating in classroom activities.

**Design Thinking:** This human-centered approach to problem-solving encourages students to think like designers, inventors, and innovators. Educators can facilitate design thinking workshops where students prototype solutions for reducing waste, contributing to SDG 12: Responsible Consumption and Production. This process helps students to iterate on their ideas, taking into account user feedback and environmental impact.

**Cross-disciplinary Projects:** Educators have found success in merging subjects to provide a more cohesive learning experience. For instance, an art and science collaboration could involve students creating installations that utilize solar energy, tapping into SDG 7: Affordable and Clean Energy while also encouraging artistic expression.

**Community-Integrated Learning:** Linking classroom projects with community initiatives enables students to see the real-world impact of their learning. A class might partner with a local non-profit to conduct energy audits for buildings, providing practical experience and community service, thus addressing SDG 13: Climate Action.

**Mentorship Programs:** Connecting students with professionals and experts in fields related to SDGs provides mentorship opportunities and exposure to real-world STEAM applications. This might include interactions with environmental scientists, engineers, or sustainability activists, who can provide practical insights and inspire students.

## Explore the role of “learning by design” educational approach in teaching SDGs in STEAM

The educational strategy referred to as "Learning by Design" is built upon the fundamental concept that education constitutes a knowledge-oriented process wherein students gain knowledge aligned

with their individual interests, competencies, and imaginative faculties. A pedagogical framework within this paradigm is the "Learning by Design" methodology. Within this approach, the knowledge acquisition process is envisioned to entail a series of learning activities categorized according to the modalities through which students can effectively acquire knowledge. In light of this perspective, Cope and Kalantzis (2015) advocate for an approach wherein educators design the learning process for various types of activities aimed at facilitating knowledge acquisition. These activities encompass: 1) the experience of the known and the unknown, 2) the conceptual approach to the abstract and theoretical, 3) the analysis of functions and perspectives, and 4) the appropriate and creative application of knowledge. Such a strategy, when employed as an enrichment tactic, fosters comprehensive learning wherein students grasp fundamental theories, principles, processes, attitudes, and beliefs transcending disciplinary boundaries, apply acquired knowledge, transfer their understanding across diverse contexts in accordance with their interests.

The notion of design in this context is dual-fold. Initially, educators act as designers of the learning process, considering the diversities and requirements of their students. Subsequently, students themselves become designers, leveraging their knowledge and knowledge transfer through active engagement in learning activities tailored to their interests, competencies, and creativity. Ultimately, the structured learning process and student-led design activities bolster the skills and motivations of learners. Cope and Kalantzis (2015) outline a range of activity types in alignment with this approach (Figure 1).

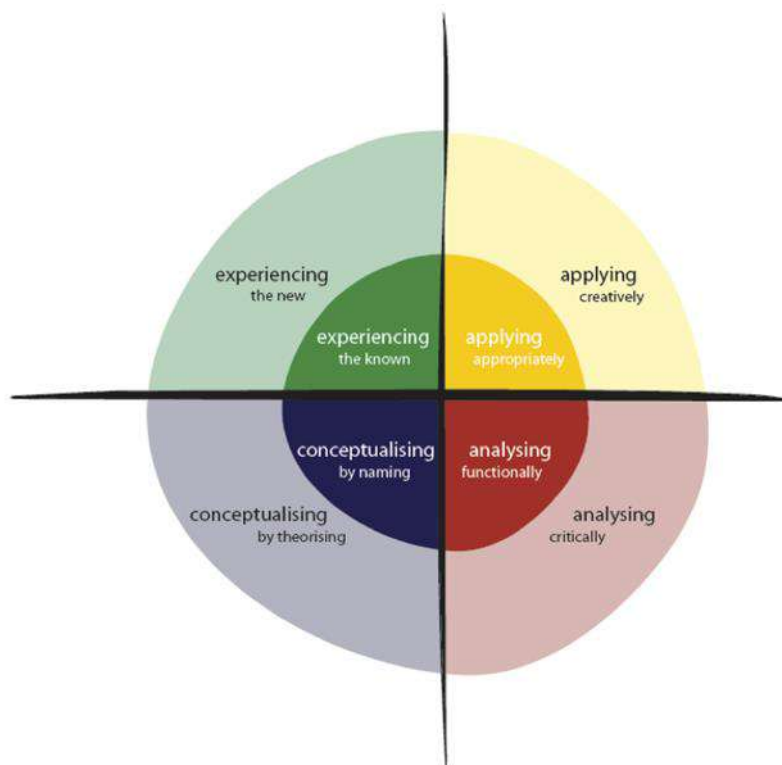


Figure 1.1: Learning by Design Activities





### (a) Experiential Learning

**Known** - Students reflect on their experiences, interests, and opinions.

**New** - Students observe or participate in unfamiliar learning situations and immerse themselves in new situations or content.

### (b) Conceptualization

**With terminology** - Students categorize things into categories, apply criteria for categorizing terms, and define them.

**With theory** - Students make generalizations using concepts and connect terms in conceptual maps or theories.

### (c) Analysis

**Functionally** - Students analyze logical connections, cause-and-effect relationships, structures, and functions.

**Critically** - Students evaluate their own opinions, interests, and motivations, as well as those of others.

### (d) Application

**Appropriately** - Students apply new learning to real-life situations and test the validity of these situations.

**Creatively** - Students make an intervention in the world they live in, which is innovative and creative, or transfer what they have learned to different situations.

## Challenges and Solutions

### Exploring Challenges in Integrating SDGs into STEAM Education

The integration of Sustainable Development Goals (SDGs) into Science, Technology, Engineering, Arts, and Mathematics (STEAM) education holds immense promise for fostering active citizenship and promoting sustainable development. However, this endeavor is not without its challenges. In this section, we delve into the various obstacles that teachers may encounter when seeking to integrate SDGs into STEAM education.

**Curriculum Alignment:** One significant challenge is aligning the SDGs with existing STEAM curriculum standards and learning objectives. Teachers may struggle to find suitable entry points within their curriculum to address SDGs effectively while ensuring coverage of essential content and skills.

**Interdisciplinary Collaboration:** Integrating SDGs into STEAM education often requires collaboration across multiple disciplines and departments. Teachers may face challenges in coordinating efforts with colleagues from diverse subject areas and negotiating competing priorities and schedules.

**Resource Constraints:** Limited access to relevant resources, such as instructional materials, technology tools, and professional development opportunities, can hinder teachers' ability to effectively integrate SDGs into STEAM classes. Budgetary constraints and inadequate support from school administration may exacerbate these challenges.

**Pedagogical Approaches:** Adapting pedagogical approaches to effectively teach SDGs in STEAM classes can be daunting for teachers. They may struggle to design inquiry-based lessons, project-based activities, and authentic assessments that authentically address SDGs while meeting the diverse needs of their students.

**Cultural and Linguistic Diversity:** In classrooms with culturally and linguistically diverse student populations, teachers must navigate language barriers, cultural differences, and varying levels of prior knowledge and experiences related to sustainability issues. Creating inclusive learning environments that resonate with all students can be challenging.

**Assessment and Evaluation:** Assessing student learning and progress in relation to SDGs in STEAM education poses its own set of challenges. Teachers may grapple with identifying appropriate assessment methods, criteria, and standards for measuring student understanding, skills development, and civic engagement related to sustainability.

**Time Constraints:** Time constraints within the school day and academic calendar may limit the extent to which teachers can dedicate instructional time to addressing SDGs in STEAM classes. Balancing the coverage of core content with the integration of SDGs requires careful planning and prioritization.

Despite these challenges, the integration of SDGs into STEAM education presents valuable opportunities for empowering students to become active and responsible citizens.

## Solutions or recommendations

To address the challenges and enhance the effectiveness of integrating Sustainable Development Goals (SDGs) into STEAM (Science, Technology, Engineering, Arts, and Mathematics) classes, several solutions and recommendations can be proposed:

**Professional Development:** Offering comprehensive professional development opportunities for teachers focused on SDGs, interdisciplinary teaching strategies, and effective integration of sustainability concepts into STEAM curriculum. Provide ongoing support, resources, and mentoring to help teachers implement SDGs in their classrooms.

**Curriculum Alignment:** Developing guidelines, frameworks, and resources to facilitate the alignment of SDGs with existing STEAM curriculum standards and learning objectives. Providing teachers with flexibility and autonomy to creatively incorporate SDGs into their instructional planning while ensuring coherence with curriculum requirements.

**Interdisciplinary Collaboration:** Fostering collaboration among educators from different disciplines to co-design interdisciplinary projects, units, and activities that address SDGs. Creating platforms and networks for sharing best practices, resources, and lesson ideas related to SDGs integration in STEAM education.

**Resource Provision:** Investing in the development and dissemination of high-quality instructional materials, technology tools, and multimedia resources that support SDGs integration in STEAM classes. Ensuring equitable access to resources for all teachers and schools, particularly those serving underserved communities.

**Pedagogical Innovation:** Encouraging teachers to explore innovative pedagogical approaches, such as project-based learning, problem-based inquiry, design thinking, and experiential learning, to engage students in addressing real-world sustainability challenges. Providing support and guidance on how to design and implement effective SDG-focused lessons and activities.

**Cultural Competence and Inclusivity:** Promoting cultural competence and inclusivity in SDGs integration by recognizing and valuing diverse perspectives, languages, and cultural backgrounds. Providing teachers with training and resources on culturally responsive teaching practices and strategies for engaging students from diverse communities in SDG-related learning experiences.

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# STEAM in SDGs

## Encouraging Students To Enhance Their STEAM Skills In Order To Address Real-World SDG-Related Challenges

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