CHAPTER 8

E→STEM Approach Applications in Environmental Education

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Introduction

Education is a complex system with a dynamic structure and every rational step in the field of education is of great importance. Education is necessary at the point of development, getting a profession, progress, equality, democracy and self-realization. Recent studies around the world focus on mastering education with a perspective away from politics and certain stereotypical educators (Colebrook, 2017). In the focus of this research, the idea of walking on more than one path at the same time rather than choosing a single path in education has been suggested, and it has been determined that the use of different disciplines together contributes to cognitive development, creativity, imagination and solving the problems encountered (Perkins, 1994). The STEM approach has emerged with the use of science, mathematics, which are the basic disciplines, engineering, which uses science and mathematics together for the design of the world, and technology, which makes science a tool in changing the world, in education.

The STEM approach has merged with disciplines such as entrepreneurship (STEM-Entrepreneurship, STEM+E), art (STEM-Art, STEAM) and programming (STEM-Computing, STEM+C) over time. One of the current interpretations of the STEM approach, created by considering the needs of the 21st century, is E→STEM, which is the combination of Environment and STEM. In order to understand the framework, impact and goals of the E→STEM approach, it is important to understand the STEM approach and 21st century skills that it is rooted in.

STEM Approach and 21st Century Skills to Understand the E→STEM Approach

STEM consists of Science, Technology, Engineering and Mathematics disciplines. The interdisciplinary approach, which emerged about 30 years ago and was first acronymous as SMET by the National Science Foundation, later took the form of STEM (Martín-Páez et al., 2019) and has taken place in the literature with this form today. STEM is a combination and is applied to comprehend situations encountered in daily life and to find solutions to problems (Siekmann & Korbel, 2016). While the STEM approach is based on constructivism and constructionism theories (Ah-Namad & Osman, 2018), it is thought to be closer to constructivist theory since it tends to measure critical thinking, creativity, productivity and entrepreneurship with performance-based evaluation (Çepni, 2017).

The new structure formed by the STEM approach disciplines is bigger than each part of the STEM disciplines (Shanahan et al., 2016). In this context, individuals who acquire a profession with the STEM approach can find original outputs with their complex competencies (Breiner et al., 2012). STEM is interested in the real problems of the world and the cumulative impact of these problems on the present and where it can lead the future.

The education that can be given with STEM disciplines can be examined in two groups, as disciplinary-focused and interdisciplinary, as shown in Figure 1 (Siekmann & Korbel, 2016).

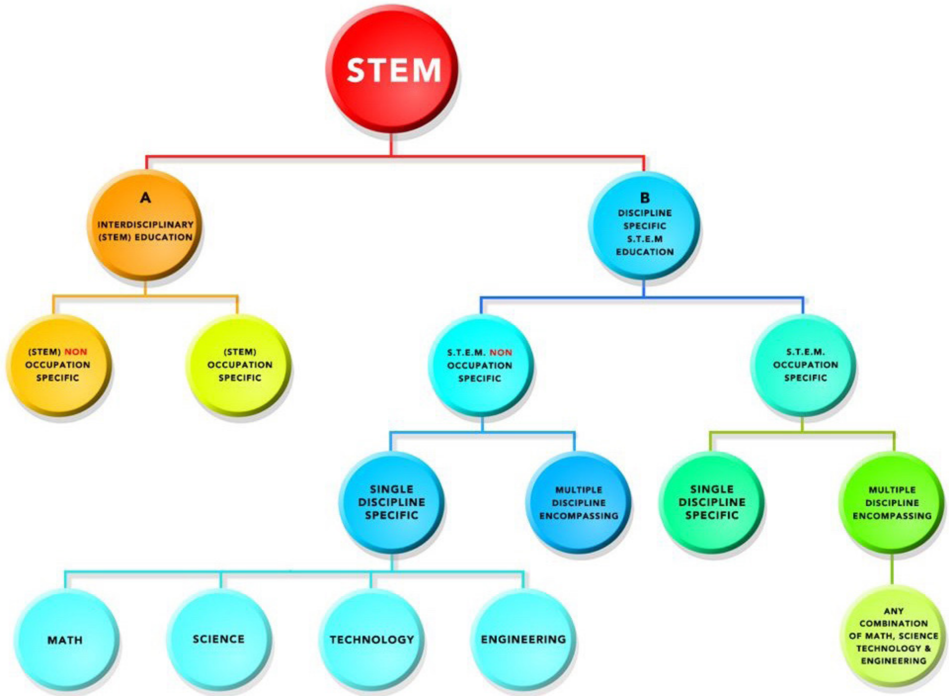


Figure 1. Interdisciplinary STEM Education and Discipline-Focused S.T.E.M Education

Interdisciplinary STEM education comes in two forms: if it is focused on STEM professions, it is a *profession-oriented interdisciplinary STEM*; *non-profession-oritented interdisciplinary STEM* if it includes an education for daily life problems. Discipline-oriented S.T.E.M education, on the other hand, is also divided into two groups as *Profession-oriented S.T.E.M education,* which can combine single or multiple disciplines, and *Non-profession-oriented S.T.E.M education*. Interdisciplinary STEM education should be the party to be chosen at this point.

Although STEM follow-up and assessment is an interdisciplinary approach with difficulties (Siekmann & Korbel, 2016), it is a meaningful educational path. This approach can provide efficient and diverse learning with the use of multiple disciplines (Takeuchi et al., 2020). The STEM approach also establishes deep ties with the skills, in other words, with the ability to produce solutions to the problem it emphasizes, to think original, to open alternative ways, and to conclude appropriate for the purpose. Skill development is a point that the STEM approach values and in this context, it attaches importance to the development of 21st Century Skills. These skills are both a building block and pathways within the STEM approach. The concept of skills takes place in international policies and systems with many different classifications (e.g. OECD Future of Education and Skills 2030, Partnership for 21st Century Skills (P21), ATSC21 skills framework, Wagner's skills framework, NRC skills framework, enGauge (NCREL) skills framework, AACU skills framework, ISTE skills framework, Iowa skills framework, Turkis qualifications framework) (Cansoy, 2018). Among these skills, the *OECD skills framework*, which sets a proficiency target for a future point in time, points out the skills that students should have in 2030, and the most researched and recognized *Partnership for 21st Century Skills (P21)* differ from the others, there is also an environmental theme in P21.

OECD (2018) skills are grouped under three headings: Cognitive and meta-cognitive skills, social and emotional skills, and physical and applied skills. These skills can be summarized as follows (OECD, 2018):

- *Cognitive and meta-cognitive skills:* These are the skills that allow students to apply their knowledge in situations they have not encountered before.
- *Social and emotional skills:* These are the skills required to communicate with other individuals, such as empathy, self-efficacy and cooperation.
- *Physical and applied skills:* Skills that require the use of dynamic and practical skills, such as using new information and communication technology devices.

P21, on the other hand, has a structure that aims to achieve the learning goals of the 21st century, to enable individuals to acquire knowledge and skills in their professional, daily and citizen lives, to be successful in the disciplines within the school, as well as to adapt to the changing world (P21, 2012).

Figure 2. Partnership for 21st Century Skills (P21) Content

Within this framework, there are themes and competencies (P21, 2019):

1. Life and Career Skills:

It refers to the development of individuals' knowledge, thinking skills, social and emotional competencies in their daily and professional lives and is examined under five headings.

- Flexibility and Adaptability
- Initiative and Self-Direction
- Social and Cross-Cultural Skills
- Productivity and Accountability
- Leadership and Responsibility

2. Learning and Innovation Skills

Learning and innovation skills, also known as 4C (Levin-Goldberg, 2012), are skills that aim to prepare students for daily life and business life in an increasingly complex world (P21, 2019). It is examined under four headings.

- Creativity and Innovation
- Critical Thinking and Problem Solving
- Communication
- Collaboration

3. Information, Media and Technology Skills

It includes skills such as accelerating access to information in the technology and media ecosystem, adapting to technological change and individualization. It is analyzed under three headings.

- Information Literacy
- Media Literacy
- ICT (Information, Communications, and Technology) Literacy

In P21, there are key subjects on which their skills are based, and 21st Century Themes based on key subjects and student success is grounded on. Key subjects were determined as English, reading, or language arts, world languages, arts, mathematics, economics, science, geography, history, government and civics. 21st Century Themes are Global Awareness, Financial, Economic, Business and Entrepreneurial Literacy, Civic Literacy, Health Literacy, Environmental Literacy.

STEM Skills

21st century skills are not recognized and unknown before, but a newly discovered structure (Silva, 2009). The STEM approach also plays a role in understanding this importance and taking concrete steps to develop skills. The STEM approach includes specialized skills as well as aiming to develop 21st century skills. STEM skills are Engineering Based Problem Solving Skill, Skills for Establishing Relevance, Engineering Based Design Skills, Innovation Skills, Digital Competence, Creativity, Communication and Collaboration (Şen et al., 2018).

Engineering Based Problem Solving Skill: Problem solving skill is the ability to eliminate an obstacle or problem (Yılmaz et al., 2018). It is structured as an engineering-based problem solving skill within the engineering design process in the STEM approach. In STEM application, it develops itself while making progress in the product creation process that leads to the definition and solution of the problem. Success in the STEM approach is closely related to this skill.

Skills for Establishing Relevance: Providing meaningful learning by integrating disciplines and knowledge with new ones. As information can be associated with new information, STEM disciplines can be associated within themselves and with other disciplines (such as art, environment, astronomy) (Şen et al., 2018).

Engineering Based Design Skills: Engineering based design skills are learning scientific concepts by students and using them for the benefit of society in solving engineering problems (Bamberger & Cahill, 2013). Mastery of the process in the engineering design process is closely related to this skill.

Innovation Skills: Innovation, which expresses a renewal in the process and in the result, is in the nature of STEM approach. STEM creates cumulative progress in its disciplines with this innovative thinking. In order to be stronger in competition today and in the future, one of the features that individuals should have at university is innovation (Yılmaz & Sünbül) and it enables progress in the fields of economy, industry and technology.

Digital Competence: Digital competence is a concept that describes technological skills (Ilomäki et al., 2011). It is defined as the basic skill of accessing and evaluating, storing and presenting information using computers and the Internet (MoNE, 2018a). Digital competence, one of the eight key competences of the European Union (2010), is also included in the Turkish curriculum (MoNE, 2018a). It is related to the concepts of digital literacy, computer science, media science/education.

Creativity: Creativity is not only a skill for STEM, but also a starting reason and a rule to be followed in the process. Creativity, which means the realization of a flexible responsibility, problem solving or product making, the result of which cannot be determined exactly (Amabile, 2012), is also among the P21 skills. Creativity that feeds curiosity and imagination is the building block of the STEM approach.

Communication and Collaboration: Communication and Collaboration, which are included in the Learning and Innovation Skills in P21 (2012), are collaborative working and communication skills. Working in harmony in the face of a question/problem means the effective use of thoughts and feelings in solving problems and in expression. Especially being able to work collaboratively is one of the important concepts for STEM.

E-STEM

It is known that new interdisciplinary approaches emerge with the association of STEM approach with other disciplines (e.g. STEAM, STEM-C), and STEM approach evolves with the advent of the new discipline. This situation occurs when the boundaries of the disciplines are erased with the new formation and a unique new structure is formed with the unity. The disciplines work in harmony, away from the selfishness of realizing their own discipline goal. One of the disciplines partnering with STEM is Environment. If a current education focused on the real problems of the world, the cumulative impact of these problems on the present, where it can lead to the future, and a solution-oriented education, STEM and Environment, namely E→STEM, is the way to be chosen.

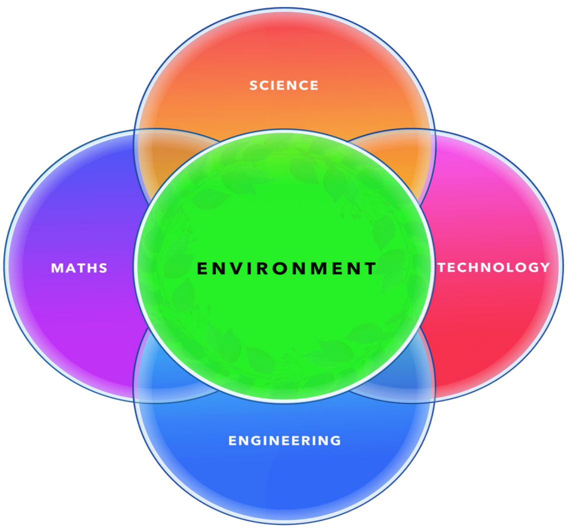


Figure 3. E→STEM Disciplines

As in STEM, E→STEM (Environment, Science, Technology, Engineering, Mathematics), which is an acronym of the initials of the disciplines, has also been expressed differently by some institutions and studies (e.g. Green STEM by the National Wildlife Federation or

E→STEM by Fraser et al., 2013, Gupta et al., 2018 and the North American Association for Environmental Education (NAAEE). Since E-STEM acronym is included in the literature as Entrepreneurship and STEM, E→STEM acronym in Environment and STEM-oriented studies (Fraser et al., 2013; Gupta et al., 2018; NAAEE, 2013) is also used in this study. E→STEM is a new concept in environmental education and is a suitable starting point for STEM delivery of environmental education (Fraser et al., 2013). In the E→STEM approach, a mutualistic partnership is established between science education and environmental education, thus achieving the goals of both disciplines together (Gupta et al., 2018).

A study was carried out by NAAEE (2013) in E→STEM and an innovative environmental education approach and the determination of rational ideas in the STEM approach, their evaluation, and a research experience aimed at solving environmental problems affecting the immediate environment with a deep research were carried out. In this context, attention was drawn to the following indicators for the development of E→STEM.

Professional Development: E→STEM professional development should be a priority.

Real connections: An environmental education should be given in which individuals experience the environment personally. Extracurricular activities are very effective in this sense.

Creativity in Critical Thinking: Creativity is important in E→STEM applications and is the condition of innovation.

Practical Synthesis: Since the E→STEM approach should be given within a program, a curriculum should be prepared with the cooperation of discipline experts and educators. For this, the first item, professional development, is important.

E→STEM includes actions and targets for the environment. The motivator of the process and the effect of the product at the end of the process are environment-centered. In addition to Engineering Based Problem Solving Skill, Skills for Establishing Relevance, Engineering Based Design Skills, Innovation Skills, Digital Competence, Creativity, Communication and Collaboration that come with STEM skills, environmental literacy, one of the P21 21st century themes, is also skills and competencies targeted by E→STEM. The E→STEM approach is in a structure that can strengthen and organicize the connection between sustainable development and STEM. However, due to the scope of environmental education, there is an environmental awareness development target. The focal points of the development/change of the E→STEM approach are briefly STEM skills, environmental literacy, sustainable development and environmental awareness.

E→STEM and Environmental Literacy

Environmental literacy consists of the combination of an individual's knowledge, skills, attitudes and behaviors related to the environment (Roth, 1992). Thanks to this combination, the individual who realizes that he is a part of the ecosystem can make beneficial choices for the environment. Responsibility and awareness are the keywords of environmental literacy.

The domains of environmental literacy, which is one of the goals of environmental education, are as follows (Hollweg et al., 2012):

Knowledge: Ecological knowledge of the environment and knowledge of sociopolitical systems.

Dispositions: Interest, sensitivity, responsibility towards the environment.

Competencies: The ability to understand environmental problems, to offer solutions, to take action for the solution of environmental problems and to base it.

Environmentally Responsible Behavior: Behavior that is desired and expected through an individual or collaborative effort to solve an environmental problem.

Context: Awareness of local, regional and global situations of the environment.

In the process of developing an environmentally oriented product in the approach, an awareness is provided by drawing attention to environmental problems, information about the environment is provided, an interest and responsibility towards the environment is gained thanks to this information, and most importantly, an atmosphere of beneficial behavior is created. With this process, which includes the conditions of environmental literacy, the link between E→STEM and environmental literacy is established.

E→STEM and Environmental Awareness

Environmental awareness, which forms the core of environmental education, is knowing basic information about the environment, taking an attitude towards the environment and showing beneficial behavior in line with this information (Erten, 2005, 2012, 2019). Environmental awareness can also be explained as a sensitivity formation towards environment (Dikmenli, 2017). Environmental consciousness, which consists of three basic dimensions as interconnected environmental knowledge, positive attitude towards the environment and beneficial behavior towards the environment, is gradually formed in individuals. When environmental awareness is mentioned, the components of environmental awareness should not be considered separately (Uzun et. al, 2019). Knowing the information about the environment is the trigger for the formation of environmental awareness. The individual starts to think about the environment by knowing basic ecological information, the role of living and non-living elements in the ecosystem, the structure of interaction and balance. The awareness and the process of seeing the environment by understanding cause individuals to have feelings about the environment. Being uncomfortable with the pollution of the environment, concern for the future of the environment, a sense of responsibility for the protection of the environment and positive attitudes towards the environment are formed. With these positive attitudes, the individual now tends to act for the benefit of the environment by taking action. The last point reached is considered to be the individual's environmental awareness. Everything in this process must be done "consciously".

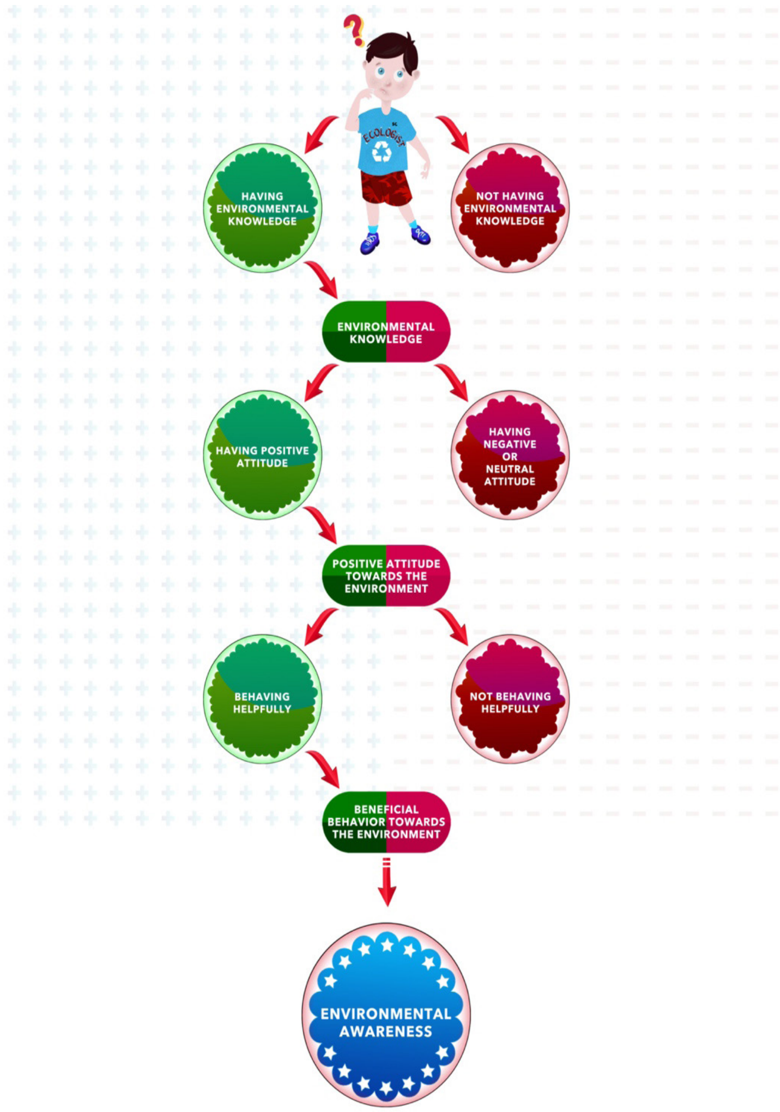


Figure 4. Environmental Awareness' Pathway

E→STEM is an effective discipline in the development of environmental awareness as well as in environmental literacy. With its structure coming from the STEM approach, the process proceeds consciously in the E→STEM approach, and this is one of the features that environmental awareness gives importance. It is in a structure that can provide all the steps for knowledge, attitude and especially behavior towards the environment with the skills and themes within it. It is seen that environmental awareness development can be achieved with E→STEM when the process of putting out a product in the step of showing beneficial behavior in environmental awareness is evaluated as taking action in solving an environmental problem.

E→STEM and Sustainable Development

Today, the concept of sustainability is used in all disciplines, and the foundations of the idea of sustainable development date back to the 19th century (Kılıç, 2012). It became known with Our Common Future published in 1987, known as the Brundtland Report (Brundtland, 1987). It is based on the philosophy of consuming today's needs by thinking of future generations without compromising their own needs. Sustainable development has also been included in the special objectives of Turkish curriculum in recent years (MoNE, 2018a). Sustainable development, which consists of three dimensions as economic, environmental and social (Harris, 2000), is the orientation of solving environmental problems based on an anthropocentric ethical approach.

Economic Dimension: The economic dimension, which is the conservation of capital and the prevention of loss (Goodland, 2002), is the conservation of available opportunities over time. It can also be summarized as the maximum economic benefit with less resource and environmental damage.

Environmental Dimension: The environmental dimension, which considers the efficient use of natural resources and the balance of the ecosystem, emphasizes the limited resources of the planet (Harris, 2000). It is the meeting of human needs by considering the balance without harming the ecosystem.

Social Dimension: It is a strong system formation where education, health and gender equality exist and everyone can access services equally. Equity, diversity, interconnectedness, quality of life, democracy and governance are its principles (McKenzie, 2004).

Sustainable development and E→STEM association is passed by African Union Commission (2015) in Agenda 2063. When the dimensions of sustainable development are examined, it is seen that E→STEM and the skills in the focus of E→STEM are also related to environmental literacy and environmental awareness. The E→STEM approach is in a structure to contribute to this multi-dimensional concept development, which is a long-term solution proposal for the solution of environmental problems.

E→STEM Approach Applications

Environmental education is important for education programs and this importance is understood more and more every day (Aydos & Yağcı, 2015). It is known that education is an effective way to find sustainable solutions to environmental problems (Artvinli & Demir, 2018). Although environmental education is given more place in educational revisions, there are deficiencies in terms of teaching materials (Derman & Gürbüz, 2018). At this point, it is thought that the outputs of E→STEM applications will be useful. The E→STEM approach is one of the most up-to-date forms of environmental education. This education contributes to the ability to think critically about the environment, the effects of people on the environment, and the interest in science professions (Gupta et al., 2018). It is also known that applied environmental programs increase the permanence of science concepts (Dieser & Bogner, 2016). While environmental education helps the effectiveness of the STEM approach, the STEM approach can offer new ways for environmental education (Kuvaç & Koç-Sarı, 2018). It is an area that has been researched on the E→STEM approach and its frame is being tried to be drawn. Nature Works Everywhere (NWE) is an sample program that includes the use of the environment in science, technology, engineering and mathematics teaching and supplementary materials for a nature-centered science teaching and has been the subject of research (e.g. Gupta et al., 2018).

Many teaching approaches can be used within the scope of the STEM approach. 5E learning model, cooperative learning, inquiry-based learning, problem-based learning are some of them. Engineering design-based science education and project-based learning have a structure that will provide a solid ground for environmental education delivered in the atmosphere of STEM approach. These two approaches, which are the most effective ways for STEM applications, will provide comfort in the integration of the environment. Reconciling engineering design-based science education and project-based learning with E→STEM and concretizing it with sample activity may contribute to the approach.

E→STEM Approach and Engineering Design Based Science Education

STEM education also includes the design process due to the relationship of engineering with innovation and problem solving (Okulu et. al, 2019). Engineering design-based science education (Apedoe et al., 2008), which is a combination of scientific research and engineering design process, is a combination of the engineering design process and the concurrent research cycle that surrounds it. One of the most fundamental aspects of this process, modeled by Barnett et al. (2008) and Wendell et al. (2010), is that students can learn from their mistakes (Kolodner et al., 2003; Wendell & Rogers, 2013). Engineering design and science teaching approaches are considered appropriate for the basic education level (Bozkurt, 2014), and the engineering design-based science education process is recommended for primary school (Kınık-Topalsan, 2018).

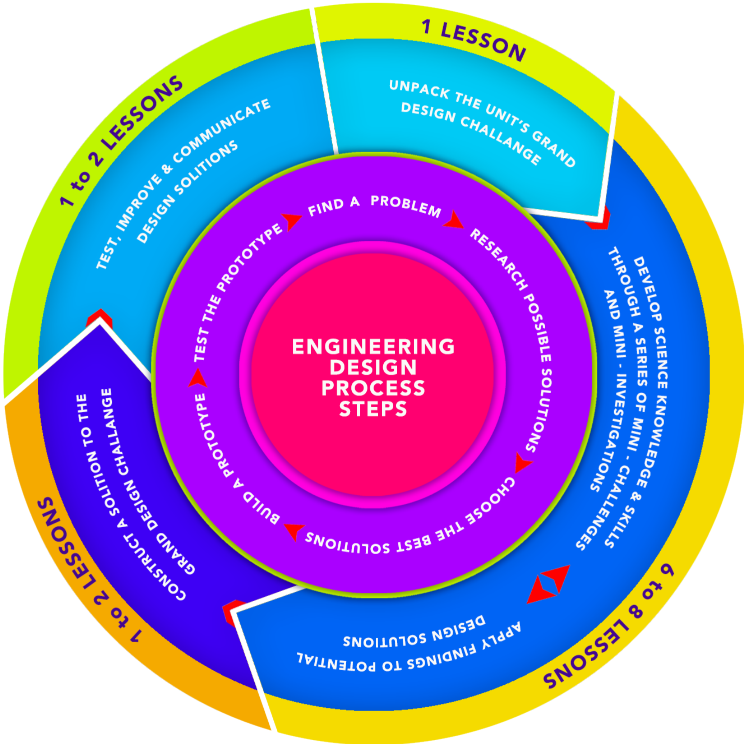


Figure 5. Engineering Design-Based Science Education Process (Wendell et al., 2010)

The processes in the two cycles in Figure 5 are carried out together in the course with the following stages:

1. Problem identification-Explanation of the major design task

2. Identifying possible solutions and choosing the best possible solution - Determining the most appropriate solution according to the expected situation from the big design task, with the students having the necessary knowledge and skills for the big design task through mini researches and mini designs. Decision-making skills are important at this stage.

3. Prototype development-Creating a prototype for the proposed and considered optimal solution for the major design task

4. Prototype testing-Developing or redesigning prototypes by testing and deficiencies

By Hynes et al. (2011) the engineering design process for the secondary education level was staged with more steps, and the freedom of transition between the steps in the process and the nature of the engineering design process ensured not to be afraid of mistakes and to continue the process. The engineering design process is illustrated in Figure 6.

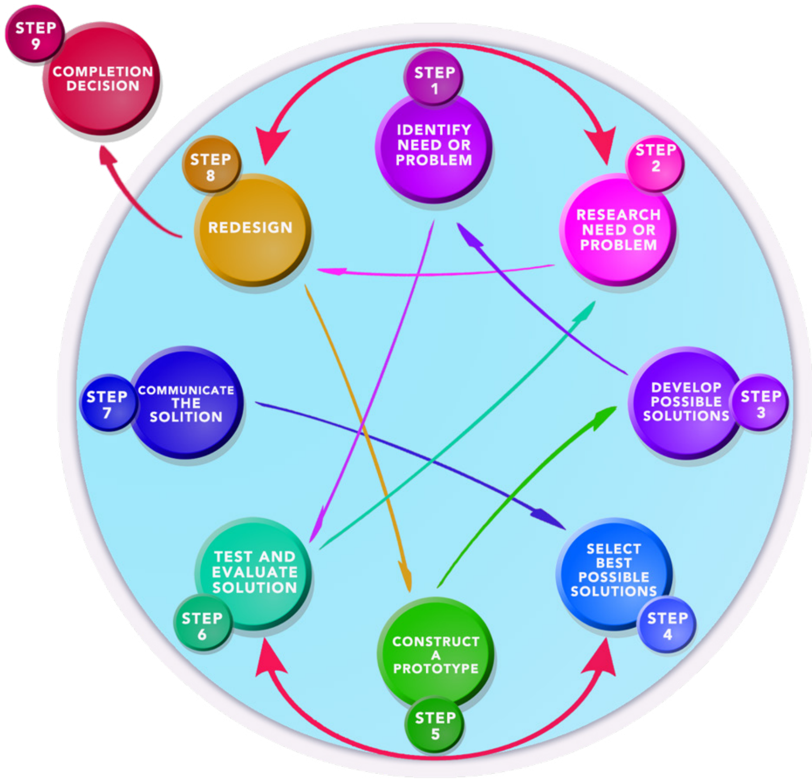


Figure 6. Engineering Design Process (Hynes et al., 2011)

It is known that the engineering design process is used for educational purposes by institutions such as NASA. The National Aeronautics and Space Administration (NASA) (2015) aims to develop STEM disciplines with its eight-step process.

In the engineering design-based science teaching process, the following can be included for the integration of the environment and its use within the scope of E→STEM:

1. An environmental problem/environment-oriented problem can be selected.
2. Environmental awareness and environmental literacy have an impact on the determination of possible solutions and the selection of the best solution. Sustainable development awareness dimensions can be taken into account while determining and selecting solutions, and environmental attitudes and environmental literacy can be developed during this selection.
3. Beneficial behavior can be targeted in the development of the prototype. Together with the product that will emerge, the materials in the emergence of this product can be selected to protect the environment.
4. It must be ensured that the resulting prototype is built with a conscious propensity

to display beneficial behavior. The environmental-oriented performances of the students at this stage can be accepted as an indicator of their environmental literacy level and the presence of environmental awareness.

E→STEM Approach and Engineering Design-Based Science Education Sample Activity

We Protect Water Activity

Grade Level: 7th and 8th Grade
Duration: 9 Lesson Hours
Goals and Achievements for E➡STEM Disciplines:

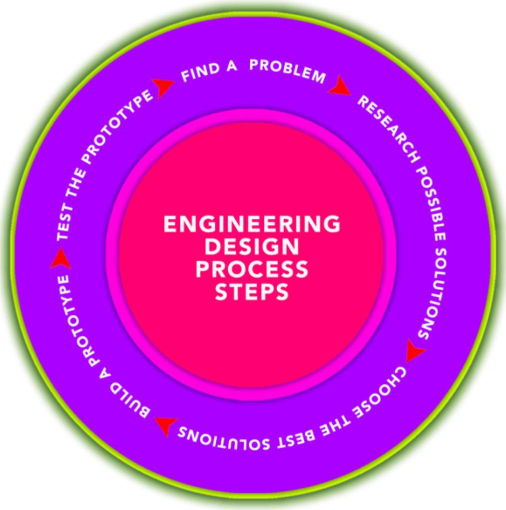
Environment	Performs the Reuse and Recyle stages of the Waste Hierarchy. Understands the importance of water. Explain the causes of water pollution. Develops projects to prevent water waste and pollution. Carries out applied environmental activities for the development of environmental awareness.
Science	F.7.4.5.2. Designs a project for the recycling of domestic solid and liquid wastes. F.7.4.5.4. Pays attention to waste control in its immediate surroundings. F.8.6.4.1. Takes care to be economical in the use of resources. F.8.6.4.2. Designs projects for the efficient use of resources.
Technology	TT.7.B.1.3. Shares the solution proposal he/she has developed for the problem he/she has determined. TT.7.B.2.1./ TT.8.B.1.1. Makes draft drawings for design. TT.7.D.1.3. Prepares the design plan. TT.7.D.1.4. Creates the model or prototype of the design. TT.7.D.1.6. Restructures the designed product according to the evaluation results. TT.8.C.3.4. Designs a product using the engineering design process TT.8.D.2.1. Prepares promotional materials for the product to be exhibited.
Engineering	Makes a product prototype. Applies engineering design processes.
Mathematics	M.7.1.1.5. Solves problems that require operations with integers. M.7.2.2.3. Solves first-order equations with one unknown.
21st Century skills	Creativity and Innovation Critical Thinking and Problem Solving Collaboration

We Protect Water Activity Worksheet

Environmental-Friendly Engineer Group Name:	
Environmental-Friendly Engineer Group Members:	**Duties**

Big Design Task

Water is one of the inanimate elements of the environment. Water, which is of great importance for the living elements of the environment (humans, plants, fungi, microscopic creatures), is indispensable. Most of our planet is made up of water. 2-3% of this water, that is very little, is fresh water. Living things can only use fresh water. Water is polluted in the city we live in, in Turkey and in the world.
Our water is polluted when we use non-biodegradable detergents, when we pour waste oil into sinks, when we empty our waste into the sea, when we unconsciously use pesticides, that is, when we act harmful to the environment. For example, frying oils constitute about 25% of the pollution load of municipal wastewater. When we pollute the waters, this water mixes with the stream or river in our city, the seas in our country, and the oceans of the world. All living things in the world can be affected by this pollution. Water pollution can also cause other environmental problems, such as soil pollution.
It poses a great threat to the lives of all peoples of the world. The return of water pollution is very difficult. Since the water resources we have are limited, they should be used very carefully.
So how can water pollution be prevented? As a nature friend, can you stop water pollution?
Can you design a model that we will use in our homes to prevent water pollution? You will be given some materials for this design. The cost of your design must be economical, your resources are limited.



1. Identifying the Problem

1. What is the problem with the big design task?

2. What should be done to solve the problem successfully?

3. What limitations exist in solving the problem?

2. Researching Possible Solutions

You identified the problem. What kind of design do you intend to make that can protect the environment and prevent water pollution? What do you need to learn for your design? Please research.

The criteria for this design are:

- There must be at least two different wastewater routes.
- Accumulation of water containing contaminants (such as oil) should be ensured.
- The hose at one end of the double outlet faucet apparatus should be at least 20 cm, and the one at the other end should be at least 70 cm.
- Maximum cost of your design is 60 ₺
- Your design should be able to hang somewhere.
- Attention should be paid to the connections to prevent leakage.

Materials:

- 1 meter garden hose (1m 4 ₺)
- 1 piece of funnel (1 piece 10 ₺)
- 1 double outlet faucet apparatus (1 x 30 ₺) Scissors (1 piece 10 ₺)
- 1 piece 5-liter waste plastic bottle or 1 piece waste liquid detergent bottle (0 ₺)
- 1 meter waste rope (0 ₺)
- Repair tape (1 m 0.5 ₺)

(Water, oil and detergent to be used jointly between groups to test the model)

Material to be used	**Amount**
Total	

You can communicate and discuss designs with other groups. Draw and explain what kind of design you intend to make.

3. Choosing the best solution

As eco-friendly engineers, you chose your materials and thought about the design to prevent water contamination. Draw your design below.

4. Making and Testing the Model

Make your design the way you planned. Test your model with oil and water.

5. Evaluating the Model

Evaluate your tested design with the help of the table below.

Criteria	Should be improved (1 point)	Moderate (2 points)	Good (3 Points)	Very Good (4 Points)
Did your model have the features you wanted?	**1**	**2**	**3**	**4**
Can your model separate water containing contaminants?	**1**	**2**	**3**	**4**
Is your model economical?	**1**	**2**	**3**	**4**
Is your model original?	**1**	**2**	**3**	**4**
Is your model useful?	**1**	**2**	**3**	**4**
Does your model protect nature?	**1**	**2**	**3**	**4**
Can your model be improved?	**1**	**2**	**3**	**4**
Total				

What concepts did you use in your design? What environmental concepts did you use?

Has your model been useful for protecting the environment? What environmental problems can it be used to solve? Please explain.

What are the differences and similarities of your model when you compare it with the models of other groups? Evaluate your own model when you compare it with other groups in showing environmentally beneficial behavior, ie protecting the environment.

What changes should you make in your model to increase environmental protection? Please explain.

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E→STEM and Project-Based Learning

Project-based learning (PBL) is a learning approach that has an old history, but has gained a place in educational environments in the 20th century and remains up-to-date (Korkmaz & Kaptan, 2001). Project-based learning puts the student at its center, but makes it active in the process by assigning responsibilities not only to the student but also to other stakeholders of education. Content-specific learning, active participation of the student and sharing what has been learned are among the principles of PBL (Krajcik, 2006).

Within the scope of PBL (also known as PjBL in the literature), there are five criteria for determining whether a project is an example or not. These are centrality, driving question, constructive investigations, autonomy and realism (Thomas, 2000). Along with the concepts of learning to learn and lifelong learning, it also serves for competences such as decision making, self-evaluation and evaluation (Tonbuloğlu et al., 2013).

Project-based learning can be used effectively in many educational levels. Taking responsibility for learning, discipline and freedom are the products of PBL (Bell, 2010). The center of PBL is pedagogy and it is not carried out within the scope of a program (Sepahkar et al., 2015). The main differences between a normal project process and PBL can be listed as follows (Sepahkar et al., 2015):

- The teacher guides the students to be on the right path during the project process. The teacher's expertise in the research subject is as important as his field knowledge.
- There are no separate tasks set for group members in the project. During the project, they experience the same experience in different ways at the relevant stage.
- Planning can be stretched in time. Progress in a certain timeline may distract from the target because students think of different ways and mistakes are considered as learning experiences.

PBL consists of stages. Until one of these stages is completed, the next stage should not be passed. It is possible to proceed with the following steps in PBL (Bell, 2010):

- The problem is determined. This problem is chosen in a way that is free from various factors.
- Requirements are determined by brainstorming about the research process.
- It is decided how the learning will be transformed as a project.

- The group, community (e.g. classmates, school administrators, parents) to whom the project will be presented is selected in accordance with the scope of the project.

The interconnection of the design processes of STEM and PBL is clearly seen. There are studies on STEM-PBL (Han et al., 2016; Han et al., 2016; Lou et al., 2017; Özçakır-Sümen & Çalışıcı, 2019), these studies have found positive effects on success and skill. STEM-PBL stages can be carried out in seven steps as identifying the problem, researching the problem, deciding on the design, analyzing ideas, making the project, testing and redesigning, communication and presentation (Çepni, 2017). PBL, whose research process is similar to STEM, can also be easily carried out with the E→STEM approach.

- In this context;
- The problem can be determined for environmental problems. In the selection of this environmental problem, the selection of the immediate environment can create effectiveness in the research process.
- Research on the problem has the potential to bring about change/development in environmental knowledge and environmental literacy.
- At the stage of turning it into a project, the criteria for creating a product and solving a problem for the environment should be observed.
- The point of sharing the beneficial behavior that will be shown as a result of the product with the target audience is in a structure that can create positive results in terms of environmental education

E→STEM and Project Based Learning Sample Activity

Zero Waste Project

Grade Level: 7th and 8th Grade
Duration: 10 weeks
Goals and Relation with E→STEM Disciplines:

Environment	Performs the Reduce Reuse and Recyle stages of the Waste Hierarchy. Realizes efficient resource usage. Prevents wastage. Carries out applied environmental activities for the development of environmental awareness.
Science	F.7.4.5.2. Designs a project for the recycling of domestic solid and liquid wastes. F.7.4.5.4. Pays attention to waste control in its immediate surroundings. F.8.6.4.1. Takes care to be economical in the use of resources. F.8.6.4.2. Designs projects for the efficient use of resources.
Technology	TT.7.B.1.3. Shares the solution proposal he/she has developed for the problem he/she has determined. TT.7.B.2.1./ TT.8.B.1.1. Makes draft drawings for design. TT.7.D.1.3. Prepares the design plan. TT.7.D.1.4. Creates the model or prototype of the design. TT.7.D.1.6. Restructures the designed product according to the evaluation results. TT.8.C.3.4. Designs a product using the engineering design process TT.8.D.2.1. Prepares promotional materials for the product to be exhibited.
Engineering	Makes a product prototype. Applies engineering design processes.
Mathematics	M.7.1.1.5. Solves problems that require operations with integers. M.7.2.2.3. Solves first-order equations with one unknown.
21st Century Skills	Creativity and Innovation Critical Thinking and Problem Solving Collaboration Communication

Questioning Phase

Rotting and crushing of food leads to wastage of food. This is called food waste. Not only in places where food is produced, but also excessive food orders, excess bread and excessive food intake are the causes of food waste in restaurants. The biggest food waste occurs in our homes.

- 1/3 of the food produced in the world is wasted every year.
- 45% of vegetables and fruits produced in the world and 20% of animal foods are wasted.
- Of the 33 million tons of garbage collected every year in our country, 14.5 million consists of food.

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Food waste means wastage of energy and water during production. This increases our ecological, carbon and water footprint. Waste pollutes the environment and causes environmental problems. Along with our resources, their access to resources is endangered for future generations. In addition to wise and planned shopping, it is also beneficial to extend the shelf life of foods in preventing this waste.

Based on this information, develop a project suitable for the question given below.

Problem Status

You opened a restaurant. As an operator, after a while, you realize that 3 kg of food is thrown away every day in the restaurant kitchen. To prevent this, you made a planned shopping by calculating the average daily consumption of vegetables, fruits and meat. However, you have seen that this is not a solution to food waste, that the food in the restaurant kitchen gets moldy and continues to be thrown away. When you investigated the reason, you learned that there is a decay related to the storage life of the food, so 1 kg of it is thrown away every day. You also calculated that you suffered financial damage because you had to buy new ones instead of these rotting foods. You know that increasing the cooling levels of the refrigerator cabinets that provide storage will also cause energy consumption and it is not an environmental-friendly behavior. You need to find a solution that will prolong the decay time of foods. How do you come up with a solution?

Students will carry out this project in the following stages:

1. Identifying the problem

It is necessary to determine the beginning of the project and to define the problem clearly.
Causes of food waste

1. (When the restaurant was first opened) No planned shopping
(21 kg of food was wasted per week due to this problem) (After the planned shopping)
Not extending the shelf life (7 kg of food was wasted per week due to this problem)

2. When the levels of the coolers to prevent food waste are increased,
it causes more energy consumption.

2. Investigation of the Problem

Research is done about the problem, solutions are developed.

In your first problem, you explored the possibility that you may still be making unplanned shopping related to spoilage of food. You have found that your purchase and need are equal, that you have made a planned shopping, and that the problem is the deterioration of the food. What should you do to reduce food waste?

Regarding your second problem, you have done research to delay the deterioration of foods, to extend their shelf life. You talked to refrigerator cabinet companies. They suggested that you can buy coolers that cool more powerfully and consume more energy. You have calculated that this will cause an increase in the invoice price due to both cost and energy consumption. You knew it was an environmentally damaging behavior that also increased the ecological and carbon footprint. In order to find an environmentally friendly solution proposal, you have searched for a substance, plant or method that will not harm health in contact with food in nature and will prevent organisms that cause decomposition. As a result of your research, you learned that oak tree leaves delay the deterioration of food and this leaf has been used in the countryside since ancient times. You have decided to produce boxes for storing foods that can be placed in the refrigerator cabinet using oak leaves.
Determine the materials needed, the cost and the work schedule.

At this stage, information such as decay, living things that realize decay, organic wastes and how they should be removed are also questioned.

3. Deciding on the design

With the necessary material, cost and work schedule research, the students determine what should be related to the prototype they will make. At this stage, students stay in touch with their friends and can brainstorm. The target audience to which the design will be presented is determined. Cost, durability, functionality, efficiency and materials to be used are determined.
In determining prototypes, the following can be discussed:

- What processes should oak leaves be made into a box?
- What is the decay time of oak leaves?
- Do oak leaves have the same effect when shredded or should they be used as a whole leaf?
- What is the environmental impact of the use of oak leaves?

4. Analyzing ideas

Prototype design is decided according to the way the project is done individually or with a group. At this stage, theoretical knowledge of STEM disciplines is used. The prototype design plan is finalized. The criterion of the prototype being environmentally friendly is also taken into account.

5. Construction phase

Prototype construction is carried out.

6. Testing and redesign

The designed prototype is tested and improvement studies are carried out in line with the results. The testing process under this project will be long-term.

7. Communication and presenting

This solution, which will prolong the decay time of foods, will not harm the environment, is environmentally friendly also economical, is presented to the target audience. As a result of all the presentations, the students communicate and share their thoughts on the designs. As a result of this sharing, the design is finalized by making changes/corrections in the design when necessary.

This design can be examined by the teacher with the performance evaluation scale.

PROJECT ASSESSMENT SCALE

Criteria	Weak (1point)	Acceptable (2 points)	Medium (3 points)	Good (4 points)	Very Good (5 points)
The work plan	**1**	**2**	**3**	**4**	**5**
Identifying needs	**1**	**2**	**3**	**4**	**5**
Doing research	**1**	**2**	**3**	**4**	**5**
Distribution of tasks (if with a group)	**1**	**2**	**3**	**4**	**5**
Project execution according to plan	**1**	**2**	**3**	**4**	**5**
Material use	**1**	**2**	**3**	**4**	**5**
Originality	**1**	**2**	**3**	**4**	**5**
Usefulness	**1**	**2**	**3**	**4**	**5**
Affordability	**1**	**2**	**3**	**4**	**5**
Environmental protection	**1**	**2**	**3**	**4**	**5**
Attention to detail	**1**	**2**	**3**	**4**	**5**
Completion of the project	**1**	**2**	**3**	**4**	**5**
Communication	**1**	**2**	**3**	**4**	**5**
Creativity	**1**	**2**	**3**	**4**	**5**
Presentation	**1**	**2**	**3**	**4**	**5**
Total					

Students can evaluate themselves on the following scale in the STEM-PBL activity:

Criteria	Should be improved (1)	Medium (2)	Good (3)	Very Good (4)
Did your project have the features you wanted?	**1**	**2**	**3**	**4**
Were you able to realize your project according to your plan?	**1**	**2**	**3**	**4**
Was your research sufficient?	**1**	**2**	**3**	**4**
Does your project prevent food rot/spoilage?	**1**	**2**	**3**	**4**
Is your project economical?	**1**	**2**	**3**	**4**
Is your project original?	**1**	**2**	**3**	**4**
Is your project useful?	**1**	**2**	**3**	**4**
Does your project protect nature?	**1**	**2**	**3**	**4**
Did you work in harmony with your friends? (if with group)	**1**	**2**	**3**	**4**
Was your presentation effective?	**1**	**2**	**3**	**4**
Can your project be improved?	**1**	**2**	**3**	**4**
Total				

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Conclusion

Education is a process that is constantly evolving and seeking the best, and for this purpose, it has been determined that combining different paths rather than following a single path provides both comprehensive and effective education. With this partnership of different disciplines, interdisciplinary education approaches have emerged. The STEM approach, which is one of the current trends of interdisciplinary education, has expanded its field of application by integrating with many disciplines and has taken a place in environmental education. Since the practice-oriented structure of the STEM approach coincides with the environmental education's goal of beneficial behavior, a partnership has been established that is pleasing to both sides. It is very important to turn the goals into action in environmental education and this is met with STEM applications. The E→STEM approach enables STEM to evolve with a deeper philosophy that considers the future rather than its economic, political or competitive bases. E→STEM, which can be applied at every level with every educational theory, approach and method in which STEM is applied, has the feature of a current approach to environmental education. At the point where environmental problems come, international agreements, sanctions or individual efforts create effects far from desired, and it is thought that nature education, namely E→STEM, will be a hope for the environment in the axis of STEM structuring the professions of the future.

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