

REPUBLIC OF TÜRKİYE
YILDIZ TECHNICAL UNIVERSITY
GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

**ENGINEERING DESIGN PROCESS IN ENVIRONMENT-
THEMED STEM MODULE: AN EXAMPLE OF TEACHERS’
PROFESSIONAL GROWTH**

Nur CENGİZ KELEŞ

MASTER OF SCIENCE THESIS

Department of Mathematics and Science Education

Science Education Program

Supervisor

Prof. Dr. Mustafa Sami TOPÇU

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A thesis submitted by Nur CENGİZ KELEŞ in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE is approved by the committee on 22.12.2023 in Department of Mathematics and Science Education, Science Education Program.

Prof. Dr. Mustafa Sami TOPÇU
Yıldız Technical University
Supervisor

Approved By the Examining Committee

Prof. Dr. Mustafa Sami TOPÇU, Member
Yıldız Technical University

Doç. Dr. Gülbin ÖZKAN, Member
Yıldız University

Prof. Dr. Ebru KAYA, Member
Boğaziçi University

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Nur CENGİZ KELEŞ

Signature



*Dedicated to my family
and my dear husband*

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LIST OF ABBREVIATIONS

EDP	Engineering Design Process
IMPG	Interconnected Model of Professional Growth
NAE	National Academy of Engineering
NRC	National Research Council
PG	Professional Growth
PhD	Doctor of Philosophy
STEM	Science, Technology, Engineering, Mathematics



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Engineering Design Process in Environment-Themed STEM Module: An Example of Teachers' Professional Growth

Nur CENGİZ KELEŞ

Department of Mathematics and Science Education

Science Education Program

Master of Science Thesis

Supervisor: Prof. Dr. Mustafa Sami TOPÇU

Examining teachers' professional growth within the Engineering Design Process (EDP) context is essential for effectively preparing educators to integrate EDP with STEM modules into their teaching methods. Professional growth (PG) initiatives can enhance teachers' abilities to facilitate meaningful learning experiences and promote interdisciplinary learning by equipping them with the necessary knowledge and skills. This improvement in teachers' capabilities will enhance student learning outcomes, better-equipping students to meet future challenges.

The significance of this research lies in its comprehensive coverage of assessing teachers' professional growth. Also, integrating environmental education into teacher PG programs with STEM modules enhances teachers' capacity to instruct on ecological and sustainability issues, thereby enriching STEM curricula. The study aimed to determine teachers' professional growth about EDP through environment-themed STEM modules.

The STEM module was designed with an environmental theme to ascertain teachers' professional growth concerning the EDP. The Interconnected Model of

Professional Growth (IMPG) developed by Clarke and Hollingsworth constituted the primary theoretical framework of the research. The Quality K-12 Engineering Education Framework by Moore et al. was used in the analysis process in the context of the IMPG, Domain of Practice, to assess the extent to which teachers apply engineering design during EDP and classroom practice. This secondary theoretical framework of the study was also used to design and develop an environment-themed STEM module.

The research was conducted in both online and face-to-face settings with different branches of teachers. Observation notes were taken throughout the program as a secondary data source. As the primary data source, the study was completed with semi-structured interviews compatible with the IMPG domains.

The current study used a multiple case study design to evaluate teachers' professional growth based on IMPG domains. Utilizing the analysis, *the teachers' knowledge* about EDP after the program was revealed (*personal domain*). Moreover, they mention *engineering education indicators (domain of practice)*, *their views on EDP lesson plans*, and students' outcomes *as silent outcomes (domain of consequence)*, as well as based on context or skills, *their opinions about the activities (external domain)* were analyzed. Based on their professional growth in the context of EDP implementation and in-class implementation, the study found four distinct types of teachers: "sophisticated," "eager," "average," and "naive."

Keywords: Environment-themed STEM module, teacher professional growth, engineering design process, inquiry-based activities.

Çevre Temalı STEM Modülünde Mühendislik Tasarım Süreci: Öğretmenlerin Mesleki Gelişimine Bir Örnek

Nur CENGİZ KELEŞ

Fen Bilgisi Eğitimi Anabilim Dalı

Yüksek Lisan Tezi

Danışman: Prof. Dr. Mustafa Sami TOPÇU

Öğretmenlerin mesleki gelişimlerinin Mühendislik Tasarım Süreci (MTS) bağlamında incelenmesi, öğretmenlerin STEM modülü ile MTS'yi öğretim yöntemlerine etkili bir şekilde entegre edebilmeleri için oldukça önemlidir. Mesleki gelişim (MG) girişimleri, öğretmenleri gerekli bilgi ve becerilerle donatarak anlamlı öğrenme deneyimlerini kolaylaştırma ve disiplinler arası öğrenmeyi teşvik etme yeteneklerini geliştirebilir. Öğretmenlerin yeteneklerindeki bu gelişme, öğrenci öğrenme çıktılarının artmasına yol açacak ve öğrencileri gelecekteki zorlukların üstesinden gelmeleri için daha iyi donanımlı hale getirecektir.

Bu araştırmanın önemi, öğretmenlerin mesleki gelişimini değerlendirmeyi kapsamlı bir şekilde ele almasında yatmaktadır. Ayrıca, öğretmenler için hazırlanan MG programlarına çevre eğitiminin STEM modülü ile dahil edilmesi, öğretmenlerin çevre ve sürdürülebilirlik konularında eğitim verme konusundaki kapasitelerini artırarak STEM müfredatını zenginleştirecektir. Çalışma, çevre temalı STEM modülü aracılığıyla öğretmenlerin MTS hakkındaki mesleki gelişimlerini belirlemeyi amaçlamaktadır.

STEM modülü, öğretmenlerin MTS'ye ilişkin mesleki gelişimlerini tespit etmek amacıyla çevre temalı olarak tasarlanmıştır. Clarke ve Hollingsworth tarafından

geliştirilen Bağlantılı Mesleki Olgunlaşma Modeli (BMO) araştırmanın temel kuramsal çerçevesini oluşturmuştur. Moore ve diğerleri tarafından hazırlanan Kaliteli K-12 Mühendislik Eğitimi Çerçevesi, öğretmenlerin MTS ve sınıf uygulamaları sırasında mühendislik tasarımını ne ölçüde uyguladıklarını değerlendirmek için BMO, Uygulama Alanı, bağlamında analiz sürecinde kullanılmıştır. Çalışmanın bu ikincil teorik çerçevesi, çevre temalı bir STEM modülü tasarlamak ve geliştirmek için de kullanılmıştır.

Araştırma hem çevrimiçi hem de yüz yüze ortamlarda farklı branşlardaki öğretmenlerle gerçekleştirilmiştir. İkincil veri kaynağı olarak program boyunca gözlem notları alınmıştır. Birincil veri kaynağı olarak ise IMPG alanlarıyla uyumlu yarı yapılandırılmış görüşmelerle çalışma tamamlanmıştır.

Mevcut çalışmada, öğretmenlerin BMO alanlarına dayalı mesleki gelişimlerini değerlendirmek için çoklu vaka çalışması deseni kullanılmıştır. Analiz sonucunda, öğretmenlerin program sonrasında MTS hakkındaki bilgileri ortaya çıkmıştır (kişisel alan). Ayrıca, mühendislik eğitimi göstergelerinden (uygulama alanı), EDP ders planları hakkındaki görüşlerinden ve sessiz çıktılar olarak öğrenci kazanımlarından (sonuç alanı) bahsetmişler ve bağlam veya becerilere dayalı olarak etkinlikler hakkındaki görüşleri (dış alan) analiz edilmiştir. MTS uygulaması ve sınıf içi uygulama bağlamında öğretmenlerin mesleki gelişimlerine bakıldığında, araştırmada dört farklı öğretmen profili ortaya çıkmıştır: "sofistike", "hevesli", "ortalama" ve "acemi".

Anahtar Kelimeler: Çevre temalı STEM modülü, öğretmen mesleki gelişimi, mühendislik tasarım süreci, sorgulamaya dayalı etkinlikler.

1

INTRODUCTION

1.1 Literature Review

In last stages of the century, there are dizzying changes and developments in science and industry. In this century, human beings have developed a free and scientific understanding of criticism to keep up with this dynamism and adapt as much as possible. A comprehensive communication network has been established from one end of the world to the other, and the borders of the countries have almost faded in the globalizing world structure. It is seen that people have evolved into a system where access is possible to nearly everyone, anytime, from anywhere. In short, it is possible to say that the “inner world of the society” of this century comprises increasingly globalized, complex, and highly mediatic societies (Beck, 1996, p. 1). This situation reveals the need for educational programs and human profiles with universal values and the skills required by the century.

Globalization of the world, not only geographically but also sociologically, is being contrived by common goals, needs, and tendencies. Although in a structure where people are becoming increasingly uniform, societies' adoption of various lifestyles can support assortment and development in multiple fields because living in distant geographies is linked to myriad cultures, economies, and historical backgrounds. This situation may prevent humanity from future emotional and psychological mechanization and homogenization (Beck, 2000).

Even if societal homogenization results from global regulation, which is needed and the foundation of the future, it is a common belief that each person is unique. In this topic, Hancock and Gallard (2004) noted that various factors, such as social, physical, emotional, developmental, and cultural structure, impact individuals, even on a teacher's instruction. Thus, it is seen that the factors that have important effects on "society and people" as the needfulness of the information and communication age are in internal interactions with each other. These factors have important effects on people and have contributed to forming different disciplines as their main fields of study.

The issues (e.g., global, and social problems, events, etc.) experienced in daily life have been comprehended and resolved with the integrity of academic knowledge, skills, and values. It can be said that humanity has a complex natural world based on scientific evidence and is surrounded by endless scientific concepts that can be understood and developed with the contribution of other disciplines. For example, when education is put at the center, many factors affect the concept of education, such as social, economic, cultural, etc. Through these factors, education-oriented interdisciplinary studies are completed using disciplines such as sociology, technology, economics, and psychology. Thus, it can be said that the globalized world order makes interdisciplinary approaches essential.

Learning and understanding new concepts change a person's capacity and performance, requiring never-ending and continuous effort (Spector, 2012). Based on this continuous lifelong process, it is reasonable to say that education should typically include a wide variety of learning activities and teaching methods due to individual differences in learning styles. Even though this fruitfulness precludes reaching a consensus on the STEM education approach, it allows diversification and enrichment.

The STEM workforce, on which policymakers are focused, requires a specific skill set to enable countries to prosper economically and support the development of new disciplines. (NAE & NRC, 2014). Developing technology and cyberization, changing workforce markets, the requirement for renewed economic models, the emergence of different business areas, and the deficiency of 21st-century skills made STEM popular (Brown, Brown, Reardo & Merrill, 2011), and the visible education approach in national and international programs and policy study (National Science Board, 2007; NGSS Lead States 2013). For example, worldwide business enterprises such as Amazon, Intel, Tesla, etc. have turned to robots and machines with artificial intelligence technology and machines that make much more profit from low-budget time and energy instead of the workforce in production lines (Okan Gökten 2018). It has become inevitable that people with a workforce that cannot adapt to this change will become unqualified employees.

According to National Science Board (2012), there are 2.4 million available open positions for every STEM-trained jobless worker. The enormous effects of this technological development, which has replaced the workforce in the production

sector, can be understood through a documentary filmed a few years ago. Before the development of drone technology, some documentaries required helicopters, pilots, cinematographers, and sound systems. Today, however, with a single drone and pilot, not only can time and money be saved, but quality documentary footage can also be produced. As can be seen from the example, while some professions are less needed in time, current developments have accelerated the emergence of new occupations. Implementing STEM education properly and comprehensively can lead to success in this regard.

Keeping up with these changes in the STEM workforce as a nation and having a voice in the global economy are extremely significant issues among countries (English 2016; Marginson et al. 2013).

Wang, Moore, Roehring, and Park (2011) indicate that;

“Growing concerns about developing America's future scientists, technologists, engineers, and mathematicians to remain viable and competitive in the global economy has re-energized attention to STEM education. To remain competitive in a growing global economy, it is imperative that we raise student's achievement in STEM subjects.” (p.1)

European educators and organizations have often talked about the necessity of STEM education to provide these skills needed in the workforce. (Kennedy & Odell 2014). Therefore, it is known that governments and industries are investing heavily in research and projects on STEM education for economic reasons (National Science Board, 2007; NAE & NRC, 2014).

Research suggests that properly integrated STEM education should combine meaningful and conceptual contexts in the four disciplines mentioned as acronyms and purposefully extend understanding to social, economic, political, and cultural contexts. To be able to make STEM education a meaningful and purposeful combination and widen understanding for students in different contexts, it is necessary to utilize an interdisciplinary approach (Guzey, Moore, & Harwell, 2014; Margot & Kettler, 2019). To be able to create a generation for the mentioned purpose, countries first need to teach their educators the new educational approaches. For this reason, it is impossible to overestimate the importance of professional growth for educators in STEM education.

It is well-known that by establishing learning environments and teaching strategies that meet the demands of the 21st century, instructors play a critical role in preparing students for the future. Programs for professional growth are crucial in assisting educators in gaining the subject-matter knowledge and pedagogical strategies needed for effective STEM instruction. These initiatives should provide educators with classroom spaces, resources, and continuous assistance to help them successfully integrate STEM topics and pedagogy.

A study conducted by Shernoff et al. (2017) examined the evaluation of professional growth and teacher education requirements for integrated approaches to STEM education. To execute integrated STEM education successfully, the research highlights how crucial it is to comprehend the unique demands of instructors. Furthermore, it has been noted that evidence-based research is essential for bridging the theory and practice gaps in STEM teacher education (Milner-Bolotin, 2018). This emphasizes the importance of ground programs for professional growth on actual data to guarantee their efficacy. Also, Galanti and Holincheck (2022) have recognized the development of an integrated STEM teacher identity as a significant aspect of fostering successful STEM teaching. This shows how important it is for professional growth programs to concentrate on STEM teacher identity development. To gain insight into the processes of teacher transformation in cooperation, researchers have turned to "the interconnected model of teacher professional growth" (Topçu et al., 2022). Designing successful programs for professional growth that encourage noteworthy progress among STEM educators requires understanding this concept.

An essential part of STEM education is the engineering design process, which allows students to learn via experience, hone their critical thinking abilities, and draw connections across different subjects. The engineering design process fosters students' scientific knowledge and critical thinking skills, which addresses real-world difficulties via logical and iterative ways (Long et al., 2020). Encouraging them to ask questions, look for information, create prototypes, evaluate solutions, participate in conversations, and redesign helps students draw links between science and engineering (Long et al., 2020). Design failure is a necessary component of the learning process that students will encounter when they iteratively evaluate and improve their design ideas (Roehrig et al., 2021). The integration of scientific and

mathematical disciplines is made possible by the engineering design process's multidisciplinary character, making it a crucial backdrop for STEM education.

In addition, fostering sustainability, social responsibility, and ecological awareness is strongly tied to the need for comprehensive professional growth programs and the vital role that environmental education plays in STEM education. There are several obstacles to integrating environmental education, such as a lack of understanding of what environmental education is all about. Comprehensive professional growth programs are required to overcome these obstacles (Sikhosana, 2022). Furthermore, for future educators to promote ecological awareness, thinking, and behavior in their professional activities, it is necessary that they build a mindset about environmental culture during their professional growth (Honcharuk et al., 2020).

1.1.1 STEM Education

Considering the historical development of STEM education and its definitions in the literature, it is seen that STEM is an acronym created by using the initials letters of science, technology, engineering, and mathematics and has become what it is today (Bell, 2016; Dugger, 2010; Jayarajah, Saat & Abdul Rauf, 2014; Yıldırım, 2016). It is important to note that STEM education is much more than an acronym, or a simple combination of disciplines taught separately in traditional education and presented as if they were independent of each other (Ostler, 2012).

When daily life problems are considered, it is understood that different disciplines contribute to the solution of the problem as a whole, even if the problems are complex. Therefore, it is not possible for students who learn disciplines separately in the lessons to produce solutions and show competencies by using their existing knowledge against real-life problems (Bybee, 2010; Corlu, 2012; Wang, Moore, Roehrig, & Park, 2011).

Numerous studies from multiple perspectives have examined the chronological development of the STEM education approach, its role in learning and teaching activities, its advantages, and weaknesses, how it integrates with various disciplines, and its significance and necessity. (Bybee, 2010; Ozkan & Topsakal, 2017). For example, Yıldırım's (2016) study is an analysis and meta-synthesis study in which 33 publications on the STEM education approach were examined. In the

study, it is understood that STEM applications have a key place in terms of providing developmental contributions such as academic achievement, problem-solving, creative thinking, scientific process skills, interest, motivation, and attitude.

Besides this, Guzey, Harwell, Moreno, Peralta, and Moore (2017) note that STEM integration plays three critical roles in the growth and learning of students. These are intended to encourage students' involvement and interest in STEM fields, improve their comprehension of STEM principles and procedures, and encourage the development of 21st-century skills in students. As a summary of the study, it would be beneficial to stress the following aspects of STEM integration.

- 21st-century skills like critical thinking, problem-solving, cooperation, and communication are prioritized in STEM integration. Therefore, students gain critical thinking skills, information analysis skills, and the ability to develop creative solutions by engaging in STEM activities. As students cooperate with their classmates to solve issues and finish tasks, they also hone collaboration and communication skills.
- STEM integration entails incorporating practical, hands-on projects and activities pertinent to students' daily lives. This may inspire more drive, curiosity, and desire to continue learning or work in STEM.
- Students can apply their knowledge and abilities across a variety of subjects thanks to STEM integration. The links between subjects may be seen by students, who can then have a greater comprehension of how they relate to one another. Students benefit from this multidisciplinary approach by understanding the value and practicality of STEM principles in dealing with challenging issues.

Additionally, political decision-makers have incorporated the STEM education method into the national curriculum due to its rise to prominence, its social and economic implications, and the fact that it has evolved into a dynamic educational strategy (Akaygun & Aslan Tutak, 2016; Hynes et al., 2011; Jeong & Kim, 2015; Kim & Park, 2012; Moore et al., 2014). It is impossible to put the STEM education approach into a single mold (Akarsu et al., 2020). Therefore, ever-changing realities and changing needs raise new areas of study and questions for more in-depth and comprehensive research on the STEM education approach.

The content coverage of STEM curriculum has gaps, despite efforts to match them with national requirements. In contrast to seeing STEM disciplines as distinct units, Stohlmann et al. (2012) underlines the necessity for a thorough and integrated curriculum that integrates STEM disciplines in relevant ways. To cover all pertinent material and preserve the integrity of each field, extensive preparation and coordination are required for this integration.

Bybee (2010) stated that with integrated education programs, students can solve modern world problems such as energy, health, and the environment. In this context, rather than teaching students the concepts in disciplines in separate and small parts (Timur, S., Timur, B. & Cetin, 2019). STEM education provides interdisciplinary and meaningful learning environments that reveal what and why students learn by associating the knowledge of students with their daily life problems. (Kennedy & Odell, 2014)

Within the framework of 21st-century requirements and demands, it is seen that the interdisciplinary approach introduced by STEM education has integrated and deepened students' knowledge from different disciplines while solving problems in daily life. (Vasquez, Sneider & Comer, 2013 as cited in Bayazıt, Akaygün, Tutak & Demir, 2018) Students can do this through STEM activities that allow the transformation of knowledge into a skill by expanding their knowledge pool. Thus, they will gain 21st-century skills such as critical thinking, collaboration, communication, social life skills, analyzing and designing and creating products, etc. (Akgündüz et al., 2015; Bayazıt et al., 2018; Yıldırım, 2016).

Bayazıt et al., (2018), while talking about the STEM education approach, emphasize how the interdisciplinary approach should be introduced by STEM education with the following sentences:

"Interdisciplinary work requires the fields to be organized around a situation or project, not in a separate coexistence, but in an integrated structure."

Similarly, Dugger (2010) mentioned that STEM education could be structured in 4 different ways. Firstly, he mentioned that each discipline could be taught separately, as in traditional education. Secondly, one or two disciplines can be emphasized more; thirdly, three different disciplines can be integrated into the other 4th

discipline. Finally, he mentioned that STEM schools opened in the USA adopt an interdisciplinary approach integrating all four disciplines.

Based on these explanations, it is possible to say that STEM teaching occurs in a traditional and interdisciplinary manner. This is tried to be visualized with the figures below. As seen in Figure 1.1, there is a conventional approach where real-life problems are solved by establishing separate relationships with each discipline. At the same time, in this scheme, it is understood that the problem of daily life can be solved by feeding from content knowledge from STEM disciplines, which are in a separate position; that is, knowledge transfer is essential to solve the problem.

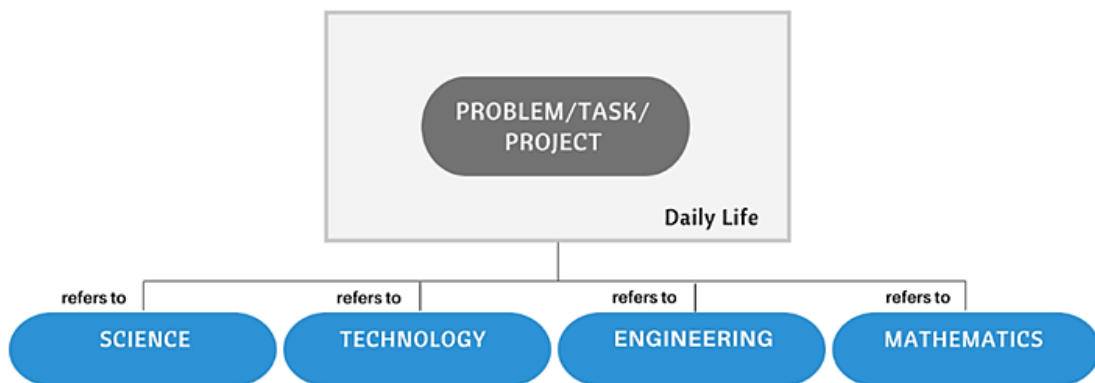


Figure 1.1 Traditional STEM education

Figure 1.2 presents a case of daily life problems involving academic disciplines. To solve this problem situation, a structure in which all disciplines contribute as much as necessary is visualized. To be more precise, the student sees STEM disciplines as meta-knowledge that is independent of the problem or task given to him/her. They find a solution by utilizing their existing knowledge. However, the interdisciplinary approach states that STEM disciplines are also fed by daily life and should not be seen as separate or higher levels of knowledge. For this reason, STEM disciplines not only contribute to the real-life problems encountered in daily life as knowledge but also feed each other with alternative innovative solutions that emerge.

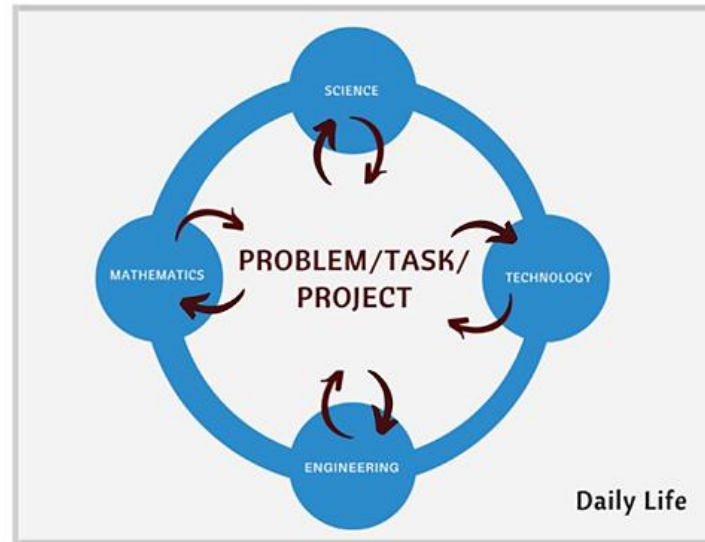


Figure 1.2 Integrated STEM education

For meaningful learning, Science, mathematics, engineering, and technology are taught in STEM classrooms holistically—that is, by combining these subjects rather than teaching them alone. As an example, Students' meaningful learning was observed to increase with a STEAM exercise created in Ozkan and Topsakal's (2020) study that helped students learn and helped clear up misunderstandings about energy conservation. From all these explanations and diagrams, it is understood what STEM education is, what kind of approach can be achieved for meaningful learning, and what skills can be gained by solving daily life problems with this approach.

The necessity for sustainable solutions and the shortage of qualified employees in STEM professions are only two of the 21st century's environmental and societal implications that are driving STEM education (Kelley & Knowles, 2016). According to research, there is a knowledge gap in how instructors perceive and use integrated STEM in their classrooms (Stohlmann et al., 2012). To effectively include STEM fields like science, technology, engineering, and mathematics in educational settings, more study and guidance are needed, as this gap illustrates.

However, there can be issues and obstacles with teachers' understanding and approaches to integrated STEM education because the speed of the developments in today's world is confusing for them, too. According to Razali et al. (2022), professional growth (PG) programs are essential for helping teachers acquire the pedagogical approaches and subject-matter expertise they require to incorporate

STEM courses into their curricula successfully. Vossen et al. (2019) address the significance of teacher cooperation and multidisciplinary methods to overcome the difficulties of implementing integrated STEM education.

More research and assistance are required to improve teachers' comprehension of and use of integrated STEM education. Therefore, professional growth programs should offer learning environments, materials, and ongoing support to assist teachers in successfully integrating STEM subjects and teaching methods.

1.1.2 Teacher Professional Growth

It is very important for children who grow up in a highly developed world of technology and science to be scientifically literate, care for universal values, and have 21st-century skills. Scientific, engineering, and technological literacy and acquiring 21st-century skills include learning to think, solving problems, and making decisions. Gaining these skills and understandings is important for all aspects of students' education and social life, from school to career life (Dönmez, 2017). As a tribute to this importance, having the necessary knowledge and skills is possible with meaningful learning processes. "Therefore, while talking about these issues, learning should be "active, constructive, deliberate, original, and collaborative" to talk about meaningful learning (Howland, Jonassen, & Marra, 2012, p.5), and these learning properties are interrelated among each other. Of course, to establish a meaningful learning environment, teachers should be educated and prepare themselves in many aspects because they especially have to adapt themselves to this century's changes and needs.

The need for individuals who are internally and externally sensitive to themselves and their environment, questioning, examining, and displaying a scientific approach to problems and producing solutions by relating what they have learned to daily life in a meaningful way prevails for students. The same goes for teachers. This need can be fulfilled by gaining 21st-century skills: critical thinking, problem-solving, communication, collaboration, creativity, and innovation (Howland, Jonassen, & Marra, 2012). Education has an important role in acquiring these skills, and it can be said that education, especially STEM education, is a turning point for the future because the STEM education approach keeps meaningful and interdisciplinary learning as the central goal for preparing children for future needs and demands. Therefore, to understand why STEM education has been so widespread and

remarkable in recent years, it is necessary to recognize this century's needs and adapt to this rapid change.

According to the 21st Century Skills Partnership, societies are known to have expectations from people. These expectations, prepared by teachers, education experts, and business and economic leaders, are considered comprehensive interdisciplinary studies for students to have the competence and skills needed at the point of work and life (P21 Leadership States 2017). In this context, it is observed that many countries make skill-based revisions in their education curricula, adjust learning environments, and organize teacher professional growth programs to transform students' knowledge into skills.

Considering the conditions of our age, the training of teachers who will be a guide and role model for the training of students with qualified workforce and skills is an important issue for many researchers.

It is a known fact that teachers need to adapt to the requirements and changes of the age beyond just field knowledge and pedagogical competencies. Bayazıt et al. (2018) in their study propose a teacher education model that can implement an integrated curriculum that adopts the model of teaching STEM fields by integrating them. Within the scope of this model, it is important that teachers from different disciplines who will apply for STEM education work together by understanding the integrated and interdisciplinary structure of STEM education. (Akaygun & Aslan Tutak, 2016 cited from Bayazıt et al., 2018).

In this context, by Weld (2017) STEM teachers are defined as

“Someone with the skills and knowledge to prepare and inspire problem solvers headed for high-demand occupations including engineering, manufacturing, health, finance, IT, and science must be a STEM teacher” (p. 81).

Based on this definition, it is clearly understood that the teachers of this century should first understand the interdisciplinary approach of STEM, develop themselves in different fields, and gain new skills. It can only be done with well-planned professional growth workshops and programs.

Many studies have shown that teachers at different levels who participate in professional growth programs about STEM education increase their content

knowledge, which in turn increases their confidence and enables efficient pedagogical practices (Lesseig et al., 2016; Margot & Kettler, 2019; Van Haneghan et al. 2015).

International Learning and Teaching Research (TALIS) study lists conferences, seminars, courses, workshops, engagement in research, enlightening talks with coworkers, class work, peer observation, assessment, teacher network involvement, etc., as examples of activities that assist teachers' professional growth.

Changes in teachers' current knowledge, beliefs, and attitudes are important to increase students' learning outcomes and give them the skills they need to work in STEM-related occupations. Therefore, by taking responsibility for their own learning, teachers benefit from professional growth programs that help them build the skills necessary for current practices (Aydin, 2018).

Teacher professional growth is the entire process of enhancing teachers' conceptual knowledge, experimenting with, and implementing new methods, developing more productive teaching strategies, and adapting what they learn to their classroom environments.

A report by the Learning Policy Institute (Darling-Hammond, Hyler, & Gardner, 2017), based on an extensive literature review, identified seven characteristics of effective professional growth (PG). These can be listed as follows. It should support the teacher's learning by providing teaching strategies for specific contexts. Experiencing the teaching strategies, they have planned or learned for their students as an active learner can move the teacher away from traditional approaches. Therefore, it can be said that it is essential for an effective PG to include active learning. An effective PG should provide space for teachers' ideas to support collaboration with colleagues, school management, and program developers. The teacher should be able to use models of effective practice and have access to lesson plans, student worksheets, peer observations, and research. It should also provide teachers with coaching or expert support in the context of their individual needs. An effective PG should support the teacher in reflecting on the practices, receiving feedback on how to adapt them to the classroom, critically evaluating the opportunities available to him/her, and making changes. Finally, an effective PG should be continuous and allow the teacher the necessary time for the learning process.

In addition to all these, the report explains in detail that even a well-designed PG program cannot be implemented well and be effective enough in teacher learning if it does not consider foreseeable barriers during the design and implementation phase. For this reason, this research was piloted to minimize foreseeable obstacles and went through revision and development stages by receiving feedback from different areas of expertise.

Effective STEM professional growth (PG) programs should incorporate a variety of strategies based on the latest findings in the general PG literature, science, mathematics and engineering, and technology PG research. Furthermore, by embracing these multiple perspectives, they can enhance the knowledge and skills of current and future educators and enable them to successfully transfer subject matter expertise to their students. As a result, it will facilitate the development of a new generation of creative thinkers who will develop professional skills in STEM disciplines and make global advances individually and societally (Averyet al., 2013; Smith, 2018).

It is important for countries to aim to create a future generation that has STEM skills and meets the expectations and demands for future professions (Bybee, 2010). In short, preparing students for the future is only possible by preparing teachers who will implement learning environments and teaching methods for the future.

Professional growth programs can be designed to prepare teachers for this aim by embracing varied perspectives. The aforementioned programs have to have the capacity to improve the expertise of both present and future teachers. This, in turn, provides them with the resources necessary to teach their pupils subject matter competence and foster the development of a new generation of creative thinkers with knowledge and abilities in STEM fields. In particular, when it comes to equipping educators for the demands of the 21st century and educational opportunities in STEM fields, the Interconnected Model of Professional Growth (IMPG) is a crucial framework for comprehending and fostering teacher professional growth. The IMPG has been extensively used in several research studies to comprehend and evaluate teachers' professional growth. It has been used, for example, to research experienced teachers' learning within the context of reciprocal peer coaching (Zwart et al., 2007). Furthermore, Schipper et al. (2017) used the framework to look at how coursework affects professional growth in

adaptive teaching ability. It also has been applied to determine how educators' knowledge, attitudes, and beliefs are changing (Clarke & Hollingsworth, 2002). These studies demonstrate the usefulness of the IMPG in clarifying and analyzing teachers' professional growth.

1.1.2.1 Interconnected Model of Professional Growth (IMPG)

To prepare teachers for the future, they should be informed about current issues, approaches, and teaching strategies and encouraged to gain experience. In this way, it is clear that teachers will have professional growth. To analyze teachers' professional growth about EDP with the environment-themed STEM module, the Interconnected Model of Professional Growth (IMPG) details used for the primary theoretical framework in this part were provided.

Although researchers frequently refer to the idea of teachers' professional growth, the phrase "professional growth," which stresses teachers' ongoing learning and the sustainability of the learning process, has proposed an alternative strategy. The word "growth" rather than "development" has been proposed by researchers including Fullan and Stiegelbauer (1991), Jackson (1974), and Johnson (1993) to stress the ongoing aspect of learning for teachers. The word "growth" was utilized in the context of Clarke and Hollingsworth's (2002) Interconnected Model of Professional Growth (IMPG).

The Interconnected Professional Growth Model has been used in several studies to understand teachers' professional growth. The model, for instance, was employed by Zwart, Wubbels, Bergen, and Bolhuis (2007) to study the learning of experienced teachers within the framework of reciprocal peer coaching. Schipper, Goei, and Veen (2017) also used the model to examine how coursework affects professional growth in adaptive teaching competency. Areljung (2018) utilized the model to examine the interviews with educators who created and deployed a pedagogical strategy for teaching science to preschoolers. The model was used by Piqueras and Achiam (2019) to examine the processes of change in educators' knowledge, behaviors, and beliefs.

More recently, the researcher Hanno (2021) utilized the model to look at teaching practices during coaching, while Gandolfi (2020) examined teachers' growth by creating NOS materials. With this model, Cheung, Shek, Hui, Leung, and Cheung

(2022) looked at teacher practice and personal domains changes. On the other hand, Zhao, Huang, Cao, Ning, and Zhang (2022) utilized the model to investigate the process of turning curriculum reform ideas into classroom practices in a teacher's coursework in China. The wealth of research illustrates the practical significance of the Interconnected Professional Growth Model in comprehending and assessing teachers' professional growth.

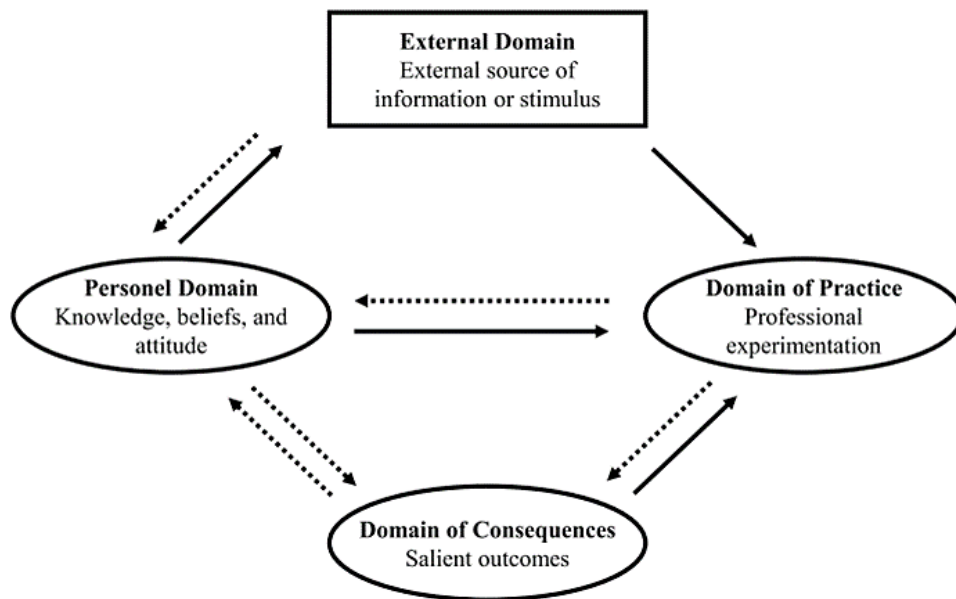


Figure 1.3 The interconnected model of professional growth (IMPG) (adapted from Clarke and Hollingsworth (2002))

To comprehend teachers' professional growth in four separate domains, Clarke and Hollingsworth (2002) created the Interconnected Model of Professional Growth (IMPG). The main keywords and explanations were written for the four different domains mentioned in Figure 2.1. The IMPG model acknowledges that learning and introspection are continual, non-linear processes in a teacher's professional growth. The model postulates that processes of reflection and practice take place in four separate domains to bring about change and growth.

- **Personal Domain**

The IMPG underlines that encouraging teacher development and change depends critically on influencing teachers' ideas, attitudes, and self-perceptions as a personal domain. Teachers' knowledge, attitudes, and beliefs are included in this area because they impact how they teach, research, and make decisions.

Implementing curriculum activities through teachers' learning and transformation processes is crucial. Curriculum activities should be created jointly with teacher development in mind. It was discovered that adjustments to the personal domain enhanced teacher abilities in instructional planning and implementation. Teacher professional growth programs may successfully promote teacher learning and growth and enhance the caliber of teaching practices if teachers thoroughly grasp the IMPG model's personal domain and approach it holistically with other domains (Farias & Araujo, 2023).

- **The Domain of Practice**

In the Domain of Practice, teachers engage in iterative processes to develop their teaching practices and pedagogical methods via reflection and application. It concentrates on the professional experiences, routines, and use of information by teachers in the classroom (Huang & Huang, 2022).

Although Clarke and Hollingsworth (2002) initially claimed that the domain of practice is typically restricted to teachers' experiences in the classroom, they later added that activities like teacher communities, professional associations, and the design of the classroom environment could also be included within the domain of practice's purview. The domain of practice also encompasses a variety of characteristics of teachers' professional experiences outside of the classroom.

The Domain of Practice interacts with other domains, such as the Personal Domain, where teacher attitudes and beliefs impact their instructional strategies. Teachers' activities inside the Domain of Practice are also influenced by issues from the external domain, such as curriculum design and educational policy (Ponte, Quaresma, & Mata-Pereira, 2022).

- **External Domain**

The personal, practice, and consequence domains in the IMPG are distinguished from the external domain as "teacher-related domains" (Clarke & Hollingsworth, 2002). The larger educational framework and extraneous effects on teachers' professional lives outside of their typical working environments are also included in the external domain (Johnson et al., 2012)

The term "external domain" also refers to the sources of information and assistance educators can use to develop novel approaches. It involves the teachers'

comprehension of novel ideas, processes, and methods developed by others. Resources, including growth as professional programs, academic readings, collegial meetings, and collaborations, are used to introduce current ideas, actions, or strategies in this field (Voogt et al., 2011).

Studies have shown that various outside sources, including books, articles, teacher forums, and contacts with coworkers, can give instructors information and support. In this way, teachers can better comprehend and utilize the resources available in the external domain, including supporting programs for professional growth.

- **The Domain of Consequences**

This domain focuses on the effects of new teaching methods on teachers and students. Results like student success, motivation, and engagement might be considered, along with the teacher's pleasure with the lesson and their influence over the classroom.

According to research, the working conditions of teachers, such as the school setting, organizational traits, and interpersonal interactions, significantly impact their career aspirations and job satisfaction. Higher rates of academic advancement and greater student accomplishment are related to favorable working circumstances. On the other hand, poor working conditions and unsupportive work cultures are linked to high teacher turnover rates, especially in institutions that serve underprivileged and minority students (Johnson, Kraft, and Papay, 2012).

The IMPG model strongly emphasizes the significance of providing supportive working conditions for teachers since this directly impacts both their professional growth and the level of instruction they deliver. Education policymakers and school administrators may promote productive working circumstances that enhance teacher retention, satisfaction, and, ultimately, student results by addressing the domain of consequence.

1.1.3 Engineering Design Process

Engineering design is defined as *"the approach engineers use to solve engineering problems—generally, [is] to determine the best way to make a device or process that serves a particular purpose"* (National Research Council [NRC], 2009, p. 49). In addition to this, it can be said that engineering is the creation of efficient and cost-effective models, products, and ideas based on societal, individual, or global

demands and issues. For this purpose, the necessary technological tools are utilized, and the knowledge gained from basic disciplines such as science and mathematics is made concrete and functional. It paves the way for other disciplines to examine the needs or issues it answers to and gain new knowledge. Therefore, engineering studies serve products or concepts that will enable these disciplines to access the latest information beyond the contributions made by fundamental disciplines. In essence, engineering uses a naturally structured methodology to identify issues and develop creative solutions. Researchers have studied this procedure, known as the engineering design process, in terms of distinct processes, methods, and the fusion of several disciplines to develop a product, concept, or system in accordance with the demands and to offer innovative remedies (Capobianco, DeLisi & Radloff, 2018; Hynes et al., 2011; NRC, 2012; Wendell, Andrews & Paugh, 2019)

According to Koculu and Topcu (2022), the engineering design process can be planned and implemented in K-12 classrooms in a learning experience that consists of methodical and iterative processes to address real-world challenges and generate solutions. This is possible because, according to the researchers, designs that succeed in challenges include engaging topics with a variety of solutions to encourage students to ask questions, seek information, build prototypes, analyze solutions, engage in discussions, and redesign. Students may use their scientific knowledge successfully and make connections between science and engineering by participating in engineering design processes (NRC, 2012). It is essential to remember that the design process is frequently iterative and entails going back to earlier processes if necessary (Craig, 2022).

Akleman et al. (2019) provide a noticeably clear and comprehensible example of interdisciplinary interaction that talks about how challenges in daily life drive engineering activities, from the development of new technological products to the use of knowledge from mathematics and science, building bridges between them, and researching and identifying solutions based on the knowledge.

The 18th century saw a tremendous development of coal mining due to the necessity for energy, bringing up the issue of floods. The invention of steam pumps by engineers was the first step in the process of extracting water, but James Watt's steam engine design was a practical and effective solution that created a foundation for thermodynamics. The knowledge of latent heat and specific heat was created

via scientific and engineering collaborations. Therefore, it is feasible to state that developments such as the creation of mathematical models and thorough theories of thermodynamics are the outcome of the interplay between scientific research and technological advancement, which also helps to promote every other field of study.

Cross, Dorst, and Roozenburg (1992) emphasize the importance of a systematic approach to student learning rather than a single "correct," step-by-step engineering design process and argue that the "consensus model" is a systematic way of organizing problem-solving behaviors. Cross (2000) emphasizes that design models typically follow an "analysis-synthesis-evaluation" structure, guiding an iterative process.

Christian, Kelly, and Bugallo (2021) claim that engineering professional growth can also have an impact on teachers' opinions of the benefits of utilizing engineering design to promote their learning, their self-confidence in their ability to teach engineering in their courses, and their capacity to provide guidance to students regarding engineering careers.

A multifaceted and iterative method is used in engineering design. Even though many models and approaches have been established, a few phases usually offer engineers an organized framework to operate inside. Depending on the basis, the processes may vary significantly, but they often involve issue analysis, research, defining requirements and limitations, idea creation, prototyping, testing and evaluation, and redesign (Winarno et al., 2020). By offering a defined framework, these phases ensure that every part of the design process is considered.

The case study methodology, which analyzes actual circumstances to comprehend the design process and its results (Dym et al., 2005), is one of the methodologies used in engineering design. Case studies describe the difficulties faced by designers and the methods they employ to solve them. The deconstruction or reverse engineering approach, in which students disassemble and evaluate developed goods, can be used in conjunction with the case study approach. According to Dym et al. (2005), this method enhances student learning growth and motivation while encouraging integrated design thinking.

Increasingly common in engineering design is another methodology called "design thinking." As Hehn et al. (2020) described, it is a human-centered paradigm that

strongly emphasizes empathy, teamwork, and iterative problem resolution. Understanding consumer wants and preferences is the first step in design thinking, which also includes coming up with a variety of concepts, prototyping, testing, and then improving on the results based on user input (Hehn et al., 2020).

In addition to this methodology, The BEST Engineering Design Model, created by NASA, is a fundamental framework that claims to instruct students on the iterative Engineering Design Process (EDP) that engineers employ. Figure 1.4 below is the NASA BEST Engineering Design Model.

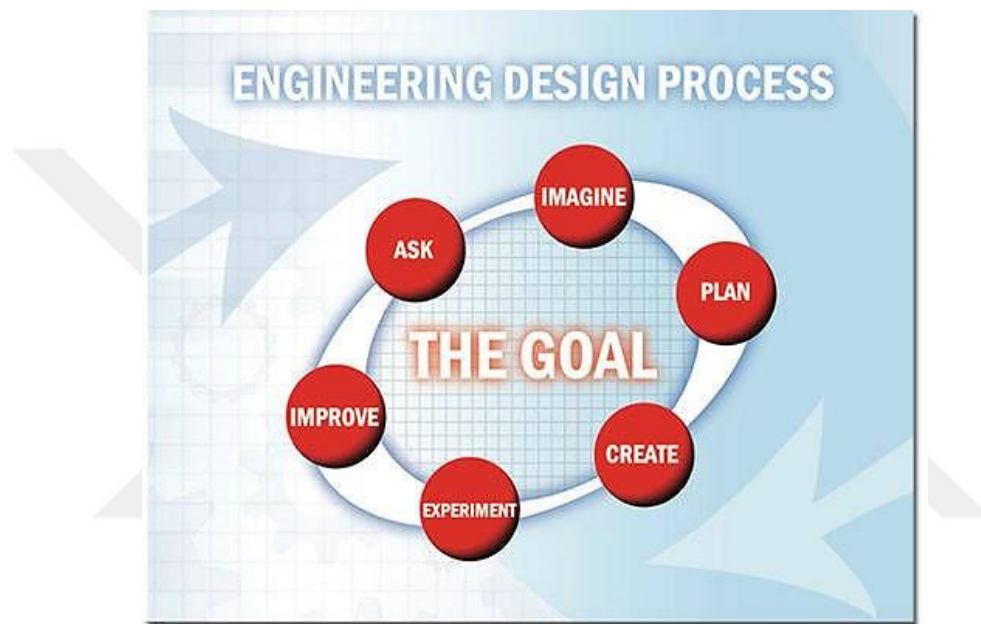


Figure 1.4 NASA’s BEST engineering design model

Students go through several steps in this process, including defining the issue, the requirements, and the constraints; generating ideas for solutions through brainstorming and research; choosing and sketching potential designs; creating a prototype; assessing the solution through testing, gathering data, and analyzing it to determine its strengths and weaknesses; and adjusting based on test results, identifying changes, and justifying revisions. These phases, which involve asking questions, visualizing, planning, producing, testing, and improving solutions, help students build their problem-solving and design abilities while also contributing to the success of missions.

The Massachusetts Department of Education (MDOE) has created a model for the design process of curriculums that uses a methodical approach to lead curriculum designers through the process of problem-solving.

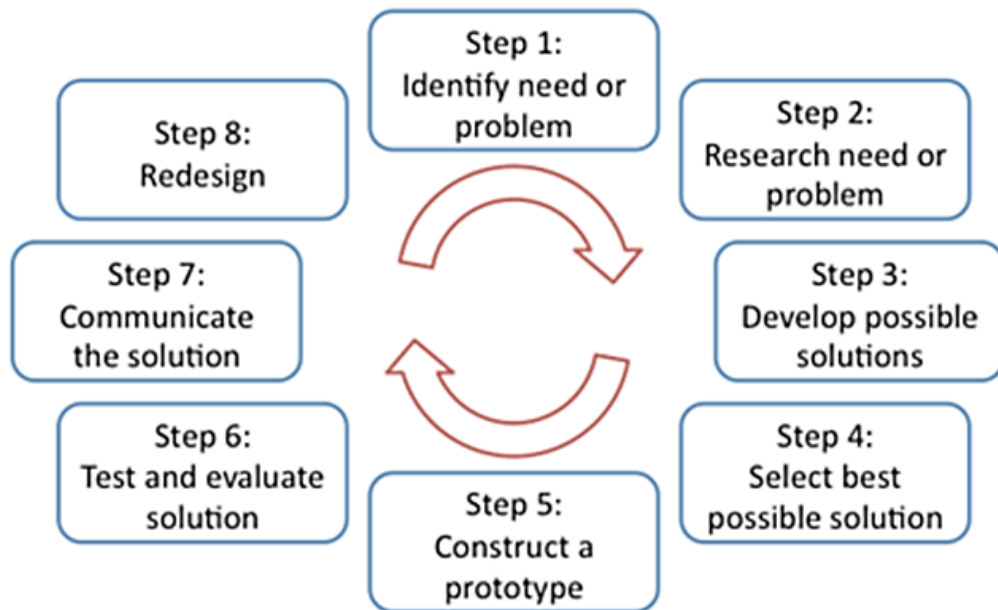


Figure 1.5 Massachusetts DOE design process model (Massachusetts DOE 2006, p.84)

The model consists of eight steps: defining and investigating problems or needs, proposing various options as multidimensional solutions grounded in mathematics and science, selecting the best solution, developing, or modeling prototypes, testing, and evaluating solutions for compliance with criteria and constraints, outlining how the solution best addresses the needs and problems and its societal impact, and at the end redesigning the solution. This methodology, which emphasizes the value of studying, synthesizing, and assessing solutions in an iterative way, is intended to promote curriculum design in the K–12 context and to offer a methodical and successful approach to creating educational programs. The disadvantage of this model is that it does not reflect the iterative nature of engineering, which emphasizes the transition from one step to a different step where it is needed, like in NASA's BEST model.

The Design Process Model, created by the Newfoundland and Labrador Ministry of Education in 2007, is a systematic approach to design that includes reflective practice and both logical and creative problem-solving.



Figure 1.6 Design process model (Newfoundland and Labrador Department of Education, 2007)

The model guides through the stages of analysis, synthesis as well as evaluation and emphasizes the cyclical nature of the process. The model offers a framework for instructors and students to build design thinking and self-directed learning abilities, which is especially important to design education because clear instructions and understanding of the design process are vital for effective learning as well as developing skills. The concept aligns with the Stanford design thinking methodology, known for its capacity to encourage creativity and solve practical issues (Soomro et al., 2021). Unlike other models, it is seen to have a web structure that shows the iterative feature of engineering.

According to Hynes et al. (2011), the engineering design process consists of nine main steps, including identifying the need or problem, coming up with potential solutions, choosing the best solution, building a prototype, testing, and evaluating the solution, expressing and resigning the solution, and coming to a decision.

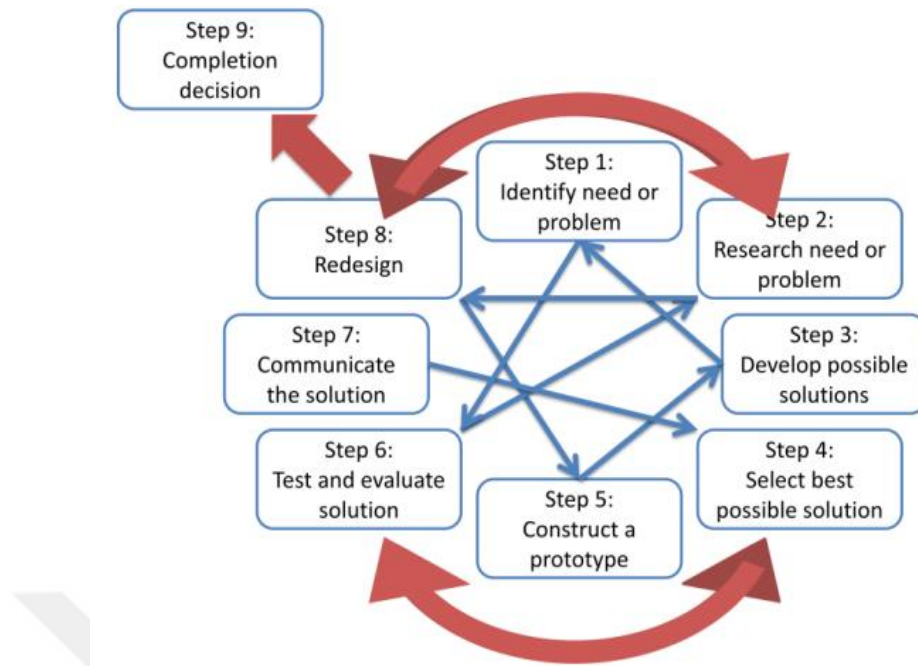


Figure 1.7 Engineering design process model (Hynes et al., 2011, p.9)

These steps provide students with practical experiences that enable them to apply their science and math learning in real-world engineering applications and develop their soft skills. Unlike other models, even if this model illustrates the iterative nature of engineering through a network structure, it is not necessarily the result of engineering. Due to the nature of engineering, the solution reached must evolve into a better one, or it must reveal new problem situations or needs.

In addition to all these EDP models, 46 research publications on the "Engineering Design Process" were examined by Arik and Topcu (2020) using a meta-synthesis technique. They found similar themes and variations in the methods applied. The research findings showed that while delivering a design brief, researchers frequently employed flexible inquiries, problem-solving scenarios, and instructional techniques, including brainstorming, laboratory, and writing exercises. Additionally, it was found that the process of creating an EDP often entails four steps: designing, producing, testing, and revising. The findings of this research served as a guide for the application of engineering design processes with teachers and aided in the formation of a comprehensive grasp of the body of literature on EDP.

The idea that teachers should take the role of learners in the process of their professional growth is supported in the literature. By gaining and using the latest information, taking advantage of learning opportunities, and honing critical thinking abilities, professionals may act like learners while developing their careers. Teachers' effectiveness and competency are enhanced by this method (Checkoway & Schön, 1985). As they recognize the value of continuous learning in their professional growth, it emphasizes the notion that educators are not just knowledge brokers but also lifelong learners (Schwartz & Schön, 1987). Based on the concept that teachers play a role as learners in their professional growth, the secondary theoretical framework for this study is the Quality K-12 Engineering Education framework (T. J. Moore et al., 2014), which was developed for all students at the K-12 level. This framework encompasses the entire Engineering Design Process (EDP) and comprises 12 indicators covering engineering fields and tasks. The framework was not only used in data analysis but also in the development process of the STEM module that addresses the EDP. It was used to analyze the 12 indicators in the context of the Domain of Practice to assess the extent to which teachers perform engineering and apply engineering design during EDP and classroom implementations.

1.1.3.1 Quality K-12 Engineering Education

The framework for Quality K-12 Engineering Education, developed by T. J. Moore et al. (2014), consists of 12 indicators to integrate quality engineering education into education systems due to legislators' decisions and educators' practices. This framework was used for the data analysis as a category reflecting the Domain of practice, which is the IMPG Domain for PG practices and in-class practices where teachers experience EDP by assuming the role of engineers to examine their professional growth about EDP. Teachers' EDP experiences were evaluated by considering the 12 indicators in the framework. At the same time, the framework was adopted to guide the development and implementation of environmentally themed STEM modules and practices that serve teachers' professional growth on EDP.

The Quality K-12 Engineering Education framework was used for data analysis, serving as a category reflecting the Domain of Practice in the IMPG Domains for PG and in-class implementations. Within this framework, teachers take the role of

engineers to show their professional growth regarding EDP, emphasizing the reflective category of the Domain of practice. Teachers' experiences with the Engineering Design Process (EDP) were thoroughly examined by evaluating their engagement with the 12 indicators outlined in the framework. Simultaneously, the framework played a pivotal role in guiding the development and implementation of environmentally themed STEM modules aimed at fostering teachers' professional growth in the context of EDP. Utilizing this framework provided a comprehensive approach to analyzing teachers' experiences, ensuring a thorough examination of their professional growth within the realm of the Engineering Design Process.

It was specifically designed for all K-12 students, intending to support and guide their development through activities where they experience learning as participants and actively engage. From this perspective, the framework was utilized in developing and implementing environment-themed STEM module that serve the professional growth of teachers and in the data analysis part for the Domain of practice. The 12 key indicators identified by the researcher are described and summarized in headings and used to support learning processes, especially in the development of activities and enabling teachers to experience EDP by taking on the role of engineers.

- **Process of Design (POD)**

Iterative problem-solving, including readiness, arrangement, and review phases, are all part of the design processes that are essential to engineering practice. To have an in-depth understanding of the topic, it is crucial for students in grades K–12 to study the fundamentals of EDP and apply them in practical settings that are based on real-life problems. In this study, teachers have the opportunity to build on what they have learned and apply EDP in an iterative process to scenarios that are aligned with real-life problems.

- **Problem and Background (POD-PB)**

Problem-solving skills are crucial for engineering, and EDP starts with analyzing and defining a problem and brainstorming on it. Students need to be able to plan multiple approaches to everyday life problems, recognize the need for engineering solutions, conduct research, acquire information according to their needs, and identify criteria and constraints when dealing with open-ended problems. This study

was structured to encourage teachers to collectively analyze the problem scenario presented to them, prompting them to seek additional information beyond their existing knowledge in order to find solutions.

- **Plan and Implement (POD-PI)**

During this stage, students discuss ideas, investigate various possible actions, assess their benefits and drawbacks, consider limitations and compromises, and eventually produce a prototype or model. While this study adopts the iterative approach of engineering, worksheets have been prepared to enable participants to pay attention to the EDP stages in practice.

- **Test and Evaluate (POD-TE)**

It is crucial to test an idea or model by developing hypotheses, planning, evaluating as well as analyzing the data collected. For data analysis, data should be collected in a variety of ways. At the same time, due to the iterative nature of design, the data helps to evaluate the benefits and drawbacks and redesign the product, idea, or solution that meets the criteria in accordance with the constraints.

- **Apply Science, Engineering, and Mathematics (SEM)**

The multidisciplinary character of engineering should be emphasized in primary through secondary school, combining knowledge of science, mathematics, and engineering. When tackling engineering challenges, students should have the chance to use the proper mathematical and scientific principles. This might happen in engineering-specific courses or by incorporating engineering design problems into math and science courses. For a thorough education in STEM, technology is purposefully incorporated as part of the engineering instruments, methods, and procedures.

- **Engineering Thinking (EThinking)**

Engineering education in the K-12 environment plays a crucial role in developing independent thinking skills, informed judgment, and problem-solving abilities. It empowers students to seek solutions, learn from failures, and embrace uncertainty. In addition, engineering develops skills such as analytical thinking, resilience, determination, metacognitive thinking, risk management, and imaginative and reflective thinking, which are essential for successful engineering practice.

- **Conceptions of Engineers and Engineering (CEE)**

Students should not just participate in EDP but also develop an awareness of the engineering discipline and the engineers' roles, including concepts such as customer focus, design constraints, and imperfection of designs. They should learn about the different engineering fields, the pathways to becoming an engineer, and the role of engineering, including aspects such as diversity, job opportunities, and expectations. Within the scope of this study, the teachers were asked to imagine an engineer and draw a picture of engineers and the working space at the beginning of the PG. The fact that they commonly imagined a male engineer and talked about engineering in the fields of construction and informatics suggested the need to include different engineering disciplines and practices in this subject. By improving the knowledge of teachers, students can gain new knowledge and develop innovative approaches to the engineering profession.

- **Engineering Tools (ETool)**

For a range of engineering strategies, qualifications, procedures, and instruments, students should be accustomed to and proficient with them by the time they complete an engineering program. Methods are step-by-step instructions for performing certain activities, skills are the capacity to carry out specific tasks, tools are things used to facilitate the job, and processes are a sequence of steps taken to accomplish specified goals. K–12 children may improve their education in engineering and their real-life skills by studying and putting these concepts into practice. This study includes different tasks that require teachers to perform mathematical calculations and create tables and diagrams using Excel. Their learning was assisted by various techniques, procedures, and resources, including using various objects to finish the application and going through the scenario creation process.

- **Issues, Solutions, and Impacts (ISI)**

Students need to be aware of the most recent advancements and critical issues, as well as the worldwide, ecological, financial, sociological, and cultural implications of their solutions to address the multifaceted and diverse difficulties facing today's society. As students get a better knowledge of the challenges encountered in daily life, they are more prepared to handle contemporary issues in the changing global

financial landscape. Each learner needs to have the necessary knowledge and awareness to tackle today's global challenge, the climate crisis. It has become important to produce constructive solutions to the problems in the desired criteria, especially by addressing the limitations of today's economic system, where the global economy is supported by unconscious consumption. For this reason, the environment was chosen as the theme of this study. All three applications consisted of a STEM module with EDP to draw attention to conscious recycling and the effective use of renewable energy sources.

- **Ethics**

The ethical issues inherent in engineering tasks should be addressed in a comprehensive K-12 engineering education. Students should learn to manage resources properly in their innovative work, keep safety at the forefront, consider the impact on natural resources, living things, and human well-being, follow ethical rules and regulations, act honestly, and respect the rights of others. Introducing students to these issues is necessary to make them realize their significance in the engineering field. In this study, teachers gave feedback to each other in the form of in-class discussions while making budget calculations after the implementation and generated ideas for more environmentally friendly and economical solutions.

- **Teamwork (Team)**

Engineering education attempts to foster students' capacity for successful cooperation and collaboration, which includes getting them involved in productive projects or activities where they play a variety of crucial roles and gain teamwork skills. This entails working toward shared objectives, acquiring crucial interpersonal abilities like listening intently, respecting different points of view, and fostering interaction and harmony among teammates. In this study, the teachers demonstrated productive and responsible roles within their own expertise by working as a group to collaborate on each application and share the results. This was further summarized in the research with a question about their contribution to group work in individual interviews.

- **Communication Related to Engineering (Comm-Engr)**

Engineering education in schools should encourage students to act like real engineers, to have excellent communication skills, and to speak in a clear and

understandable manner. Engineers explain their ideas and procedures in technical writing that are specific to their field to speak to professionals who are familiar with these jargon-filled terms. However, engineers should be able to express their technical ideas more clearly for non-engineers using non-technical language. This includes preparing client reports, making presentations, and using various representations, such as symbols and visuals, in a real-world context. In this study, the teachers' understanding of engineering tasks led them to revise their lesson plans with a rubric for students to assess their progress. The rubric mentions group work, solutions, and fulfillment of criteria and constraints, and it includes a section on effective presentation skills.

1.1.4 Environmental Education

Understanding environmental education's historical and international context is critical to formulating effective policies and programs. Environmental education is a concept formalized at the Keele University conference in 1965. However, the origins of the term date back to the 1948 meeting of the International Union for Conservation of Nature and Natural Resources in Paris. Over the last 25 years, with increasing awareness of global environmental issues, efforts to define environmental education have strengthened, and the 1970 IUCN conference led to the adoption of a broad definition emphasizing a holistic understanding. International organizations raised awareness by promoting environmental education, particularly in the 1970s, and these efforts culminated in establishing the UNESCO/UNEP International Programme for Environmental Education in 1975 (Lidstone & Stoltman, 2012).

With this historical connection, environmental education today is more than just the transfer of knowledge; it is the vanguard of raising environmental awareness and responsibility on a global scale. The impact of environmental education can, therefore, be considered separately in terms of outcomes for students and teachers. According to Esa (2010), environmental education is essential for encouraging social responsibility, sustainability, and ecological awareness among students. It fosters a thorough comprehension of ecological processes, a sense of environmental responsibility, and the ability to think critically and solve problems (Sikhosana, 2022). Along with academic preparation, environmental education fosters ethical

ideals and a feeling of global citizenship in students—a critical skill for managing an increasingly linked world (Gorbunova et al., 2021).

The integration of environmental education and teacher professional growth has significant promise for creating an all-encompassing and forward-thinking educational framework. Teachers may easily include sustainability themes into their curricula and offer a cogent approach to holistic learning by implementing environmental education principles into their professional growth programs (Lin et al., 2023). Additionally, promoting cooperation between local communities and schools to promote sustainable projects, professional growth, and environmental education together encourages citizen engagement (Al-Matroushi & Alkiyumi, 2022). The literature also emphasizes how environmental education affects teachers' growth and outcomes for students. Environmental education is important for developing students' critical thinking, ecological awareness, and problem-solving abilities—all of which are needed for STEM education (Cullis, 2019). Moreover, incorporating environmental education into teacher professional growth programs improves teachers' ability to teach sustainability issues, which enriches STEM curricula (Isungset et al., 2021).

1.2 Objective of Thesis

This study aims to determine teachers' professional growth about Engineering Design Process (EDP) through environment-themed STEM module and to identify their professional growth regarding EDP practices.

1.3 Research Questions

The Interconnected Model of Professional Growth (IMPG) by Clarke and Hollingsworth serves as the theoretical foundation for this study, comprised of multiple case studies. Through the domains of the IMPG Model, the participants' professional growth may be handled in a multifaceted and integrated way. That's why the researcher identified the research questions with sub-questions to reveal teachers' professional growth based on the IMPG domains. Therefore, the following research questions served as the study's guide:

How is the professional growth of teachers in engineering design process (EDP) with environment-themed STEM module?

The sub-problem statements are as follows:

- What is teachers' knowledge level in terms of EDP (personal domain)?
- How do the teachers assume the engineering role and reflect engineering practices during the EDP and classroom implementations (domain of practice)?
- What are the teachers' experiences with content or skills as an external source of knowledge and preferences for the learning environment as a source of external stimuli during EDP and classroom practice (external domain)?
- What is the level of teachers' qualified explanations as salient outcomes in terms of lesson plans and learner outcomes (domain of consequences) when they act as students during EDP implementation and when they act as teachers during in-class implementation?

1.4 Assumptions

- The responses of the teachers in the research sample to the interview questions reflect their sincere opinions.

1.5 Limitations

- The implementation period of the research is limited to a total of 8 days, 4 weekends and 5 class hours per week.
- The research is limited to the 2021-2022 academic year.
- It is limited to environment-themed STEM module prepared by the researcher.

1.6 Significance of the Study

For several reasons, it is important to look at the professional growth of instructors within the framework of the Engineering Design Process (EDP). In today's increasingly technological and technologically advanced world, it is imperative that students have 21st-century skills, scientific literacy, and an understanding of universal values. This encompasses the critical thinking, problem-solving, and

decision-making skills that are essential to technical, scientific, and engineering literacy (Topçu & Çiftçi, 2023). Giving students access to curriculum resources that employ engineering design as the organizational framework for creating STEM-based learning experiences should also assist instructors in adopting STEM integration (Donna, 2012).

The research is significant as it might expand upon the current body of knowledge by examining teachers' professional growth in the framework of EDP, a crucial component of STEM education (Kelley & Knowles, 2016). Also, the study has the potential to improve STEM education approach by offering insights into teachers' EDP knowledge and the roles they play during implementations. (Kelley & Knowles, 2016; Duong et al., 2022; Linh & Huong, 2021; Winarno, 2020). This research can improve experiential learning by investigating teachers' experiences with outside knowledge sources and their preferences for the learning environment during EDP and in the classroom. This will result in more engaging learning opportunities for teachers and students (Long et al., 2020). Additionally, by evaluating the degree of teachers' qualified explanations regarding lesson plans and learner outcomes during EDP and in-class implementation, the study has the potential to drive improvements in instructional strategies and promote a more effective teaching and learning environment (Diep et al., 2023).

To sum up, examining professional growth for teachers within the framework of the Engineering Design Process is crucial to equipping educators to successfully incorporate STEM learning and the EDP into their teaching strategies (Donna, 2012). Professional growth programs can help teachers become more capable of facilitating meaningful learning experiences and fostering interdisciplinary learning by providing them with the knowledge and skills they need (Topçu & Çiftçi, 2023). This will ultimately improve student learning outcomes and better prepare students for future demands. This makes the research significant as it encompasses the PG program and activities designed to determine teachers' professional growth through EDP.

2 METHODOLOGY

2.1 Design of The Study

Researchers find the multiple case study technique advantageous due to its capacity to scrutinize both the commonalities and disparities among various instances or examples. According to Johnson and Stake (1996), this approach offers a strong framework for understanding and interpreting complicated phenomena connected to teachers' professional growth. It is useful for providing light on variations across examples and allowing comparisons, which helps researchers find new perspectives on the subject they are studying. Compared to other research methodologies, the multiple case study methodology gives the possibility of a complete dataset and deeper analytical depth. Furthermore, the case study approach has been recognized for its value in educational environments and provides researchers with the chance to explore the nature and scope of case study research as well as its usefulness in these settings (Bonney, 2015). This highlights how important it is to use the case study technique to understand educational processes and provide useful recommendations for academics.

Using a multiple case study design, the study sought to closely examine and comprehend these teachers' professional growth across domains outlined in the IMPG in the context of their learning and experiences with an environment-themed STEM module. This study evaluated each participant teacher as an individual case, allowing for a thorough examination of their unique experiences and responses during the PG program. The multiple case study technique was deliberately used in the study to dive into the subtle dynamics and variances in professional growth trajectories seen among educators involved in this activity. The study examined teachers' changes, adaptations, and insights via the lens of the IMPG domains, which included the personal, practice, external, and consequence aspects.

Semi-structured interviews were conducted in Turkish and were transcribed verbatim. After that, the translations were translated into English. The transcripts were proofread by a researcher and an expert who had completed a master's thesis in STEM education. Researchers coded independently and compared the results to

ensure reliability. Researchers read over the transcript again and discussed how to reconcile any discrepancies before reaching a final judgment if they could not agree on the coding and categorization. Participants were told that the confidentiality of their personal information would be protected for ethical reasons. Each participant confirmed their willingness to participate in the study by filling out the consent form. Extensive details on the research context and participants are provided for transferability. To fulfill confidentiality and privacy requirements, the names of all participants must be kept anonymous. Eventually, each participant was assigned a number. The results are corroborated by direct quotes from the instruments used to collect the data for confirmability.

2.2 Participants

A criterion sampling technique was used, and two criteria were determined by the researchers: teachers from different branches and having at least one year of teaching experience. Based on this, the number of participants who participated in all the applications and interviews was determined to be ten. The study started with 12 participants, indicating an intention to include a relatively small but diverse group of teachers in the research. The final number of participants for analysis and interpretation is 10, as these individuals participated in all applications and interviews.

Teachers from different branches of criterion ensure diversity in the sample, allowing for a broader representation of experiences and perspectives related to the EDP with an environment-themed STEM module. In addition, teachers from different disciplines, such as mathematics, science, and technology, are enabled to see how different perspectives relate to their own expertise and experience a dynamic PG program. In this way, it is aimed to draw attention to the holistic structure of STEM disciplines that support each other. At Least 1 Year of Teaching Experience criterion is intended to include participants with a certain level of teaching experience, assuming that this duration brings a level of expertise and familiarity with teaching practices.

Table 2.1 Demographic information of teachers

Participants	Gender	School Type	Fields of teaching	Experience (year)	Preferences for learning environments
P1	M	Public	Mathematics	7	Online
P2	F	Public	Mathematics	5	Online
P3	M	Public	IT	6	Online
P4	M	Public	Mathematics	7	Online
P5	F	Public	Mathematics	6	Online
P6	F	Public	Mathematics	1	Online
P7	F	Public	English	5	Online
P8	F	Public	Science	9	Online
P9	F	Private	IT	4	Face-to face
P10	F	Private	Science	3	Face-to face

In table 2.1, private school teachers consisted of 1 science teacher and one information technology teacher. Public school teachers consisted of 5 mathematics, one science, one information technology, and 1 English teacher. Gender distribution of the participants: Out of 10 participants, 3 are men, and 7 are women. Only Participant 6 has a year of instructional experience, whereas the other participants all have more than three years of teaching experience.

The documents were prepared for conducting research in MoNE schools and Ethics Committee permissions, and approval was obtained by making an official application. At least six school administrators were interviewed to determine the schools where the implementation would take place. Finally, two schools were identified, one public and one private school. A total of 12 teachers who met the criteria were interviewed with the suggestions of the school administrators working in these schools. Teachers were informed about the thesis research and the process, and their written consent was obtained for their voluntary participation.

2.3 Procedure

A 4-week professional growth program was planned for the STEM module. Consisting of 3 different inquiry-based activities and related EDP activities, the

program was organized for two days on weekends only. These activities are as follows.

1.1 Wind Power (Inquiry-based activity)

1.2 Wind Tribune Farm (Installing wind tribune at the site selected for the customer)

2.1 Getting to Know the Plastics in Our Lives (Inquiry-based activity)

2.2 Stickman Animation Company (Creating stop-motion for the company)

3.1 Let's Heat Water Without Polluting Nature (Inquiry-based activity)

3.2 SES (Solar Energy Systems) (Installing solar panels on the roof of a building for the customer)

The activities consisting of two components are environment themed. The first part, which was intended to be the main learning area, was developed as an inquiry-based activity involving disciplinary core concepts and mathematical calculations related to the environment. Based on the learning in the first part, the second part activities were designed with a scenario involving a problem situation. This part was planned to enable participants to take on more of an engineering role and experience the engineering design process.

A workshop schedule was created to start implementing face-to-face workshops with private school teachers and online workshops with public school teachers. The schedule was shared with the teachers and reorganized to ensure everyone's participation. PG programs poster was prepared to inform teachers, as seen in Figure 2.1.

ONLINE / IN-FACE
**TEACHER
PROFESSIONAL
GROWTH
PROGRAM**

Engineering design process
with Environment-themed
STEM activities

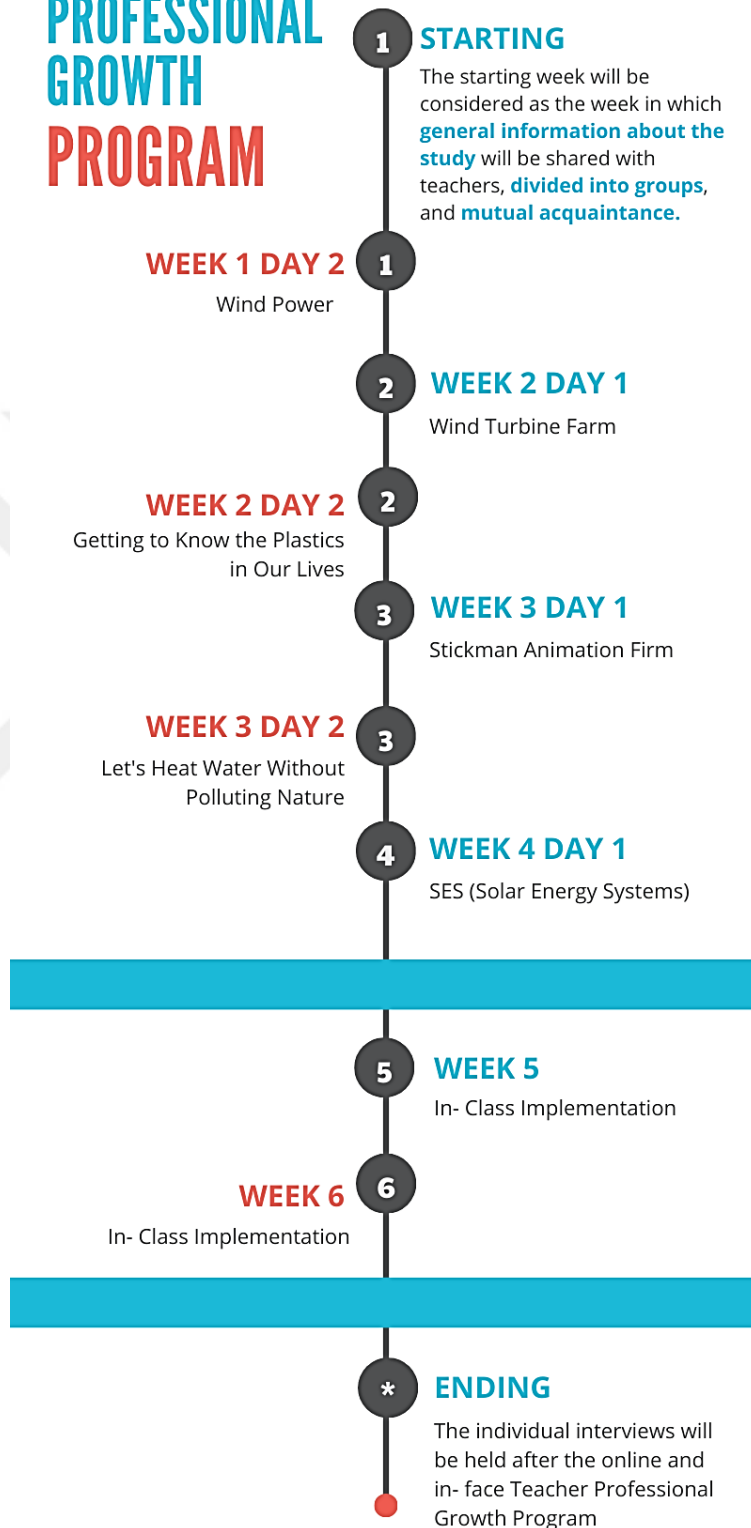


Figure 2.1 PG program

On the first day of the first week, general information about EDP and the process was shared. On the second day, the "Wind Power" activity, which is an inquiry-based activity, was introduced to the teachers. A demonstration was made, and a discussion was held on what could be expected to be learned from this activity. This activity is about finding out what kind of symmetrical or asymmetrical design would be efficient using an 8-leaf wind rose. For this reason, after one petal of the wind rose used in the activity was cut, measurements were made on how far away the hairdryer was held and how far the wind rose stopped spinning.

In the 2nd week, on the first day, an in-class discussion was held on the historical development of wind turbines based on learning about the effect of wind rose design. In 1888, the American inventor Charles F. Brush designed the first automatically operating wind turbine, and today's wind turbine designs are compared and emphasized. Through this example, it was explained that engineering develops over time and transforms iteratively to find more efficient, more ideal solutions instead of reaching a definite result. Afterward, a scenario was presented in which the participants prepared a proposal file for one of the three customers who wanted to install a wind turbine farm. The participants were provided with a wind atlas of Turkey, the necessary information about five different wind turbines in the market (real data was used), and the information about how much energy demand customers A, B, and C have in which region, as shown in the Table 2.2 and Table 2.3 below.

Table 2.2 Locations and demands of different clients for the 1st activity

		Region		
Customer	Power Demand	Location	Color Code	Average Wind Speed
A	2500	Canakkale hilly	red	10,75
B	2000	Aydin coastal		5,50
C	300	Pınarbaşı hilly		9,25

As a result of the group work, they presented their proposal files to the other groups, and the EDP activity was completed with an in-class evaluation.

Table 2.3 Detailed information about different wind turbines

Wind Turbine No:	Power (w)	Type	Wind Speed (m/s)			Price
			Minimum	Nominal	Operating range	
1	1000	Horizontal shaft with 3 blades	2,5	12,5	3-25	1.000,00 \$
2	400	Horizontal shaft with 3 blades	2,5	13	3-25	550,00 \$
3	1600	Horizontal shaft with 5 blades	2	12	2,5-25	1.550,00 \$
4	200	Vertical shaft with 5 blades	1,5	11	2-27	269,00 \$
5	400	Horizontal shaft with 3 blades	2	13	3-25	580,00 \$

On the 2nd day of the 2nd week, with the inquiry-based activity "getting to know the plastics in our lives," awareness was gained that some plastics cannot be recycled, and that each plastic has a code accordingly. For this purpose, the participants were shown diverse types of plastics and asked to categorize them in a way that they themselves determined. Afterward, they were expected to add their observations and tests to the comparative test table and make inferences by making use of the section containing technical information about the type of plastics. In this way, it was aimed to get to know the usage areas and properties of plastics in our environment more closely. In the 3rd week, on the first day, the information obtained from the activity about plastics and the scenario with the job offer of the "Stickman animation" company was shared. They were asked to prepare a proposal file for a low-budget stop-motion video that aims to raise social awareness about plastic waste. At the end of the group work, the proposal file was presented to the other groups about their scenarios, budget, and alternative materials used.

On the 2nd of the 3rd week, a new inquiry-based activity, "Let's heat water without polluting nature," was completed. Since the study was conducted with the teacher group, a discussion was held on what could be gained from this activity instead of practicing the whole activity from the beginning to the end. The activity was about making a solar collector using different colored garbage bags. It aimed to examine which factors affect this situation by looking at the measurements made at various times. With the acquisition that even minor changes in solar collectors will be effective, the "Solar energy system" EDP activity was carried out on the first day of the 4th week. In accordance with the scenario, work was carried out on the

preparation of the necessary proposal file for the solar panel installation of the Innocent apartment building in Antalya (Table 2.4).

Table 2.4 Locations and demands of client for the 3rd activity

Region	Installation Area (m ²)	Power Demand (w)
Antalya	75	15000

Technical information on solar panels in the current market (real information was adapted and used) and Turkey Solar Atlas were shared with the participants. They were expected to find the position of Antalya in the Turkey atlas and make calculations based on the annual sunshine duration in Table 2.7. In this way, it was tried to find out which solar panel would amortize the cost how long it would be installed, and how this would be reflected on the bill.

Table 2.5 Detailed information about different solar panel

Solar Panel No:	Power (w)	Price	Width (cm)	Height (cm)	Area (m ²)
1	300	2183 TRL	100	165	1,65
2	400	2973 TRL	100	210	2,1

The table 2.5 and Table 2.6 and map shared with the participants.

Table 2.6 Initial calculation results for the customer request

Calculations by solar panel type		
Number of panels required to meet power demand	Area required according to the number of panels (m ²)	Power supplied by number of panels
50	82,5	15000
38	79,8	15200

Both panels meet the customer's power demand. However, for both panels, the area provided by the customer exceeds 75m². The sizes of my solar panels are different, they cannot place all of them on 75m² and cannot break the panels. Then they have to calculate how much power will be generated again over the area required for each panel.

Table 2.7 Calculation of the results obtained by reducing the number of solar panels to fit in a 75m² area

			Grid			Hours					
End of Installation				in case of solar panel	in the absence of solar panel	Daylight	Night	Total Daily Bill	Daily Bill If the system wasn't Installed	Profit	Depreciation Period
Power (w)	No. of Panel	Price	Power from Grid (w)	TRL/h	TRL/H	8,3	15,7	333,2	486	152,8	643
13636	45	TRL 98.235	1363,6	1,8	20,2	15,3	317,9				

Before starting the PG program, an information technologies teacher with a master's degree working in a public school and a science teacher with a master's degree working in a public school were interviewed. The science and information technologies teachers, whose field of study is STEM education practices, were briefly informed about the thesis, and a pilot application was carried out on the online platform. In the real application, how to be more efficient in conducting the PG program online and the issues that need to be improved in the content were discussed with the teachers, and feedback and suggestions were received.

In this context, these are important points;

- Alternative platforms should be prepared and tested in advance to avoid technical problems on the online platform,
- Student groups can be divided into different rooms in the online system
- The researcher can act as an observer in these groups and guide them when needed,
- Since it is an online application, the visuals in the content should be enriched,
- The timing needs to be reconsidered as it is taking longer than planned,
- The problem situation in the scenario is clear, but guidance is needed in using the data presented to seek solutions,
- Giving hints to each group when necessary to avoid distractions from the work,
- The study can be difficult to implement in large classes, especially in public schools, so online implementation is a suitable alternative

-For classroom implementations, considering the average achievement in public schools, interest, and motivation in scientific studies, not all students will show the same willingness; therefore, smaller but more willing students can be worked with, and the questions that will keep the attention on the study again should be increased.

The workshop program was completed in 4 weeks with three different applications and lectures. After the literature review, previously prepared individual interview questions were adapted to the theoretical framework. Before starting the interviews, expert opinions were received from 3 different Ph.D. students for semi-structured interview questions and finalized questions because of the necessary arrangements.

2.4 Data Collection

Individual interviews were conducted with each teacher at the end of the training. All activities and interviews were conducted using the most convenient and free online platform for public school teachers. The audio recording was taken during the study with private school teachers because all processes were done face-to-face. These differences in the research setting are due to the participants' preferences, so the researcher did not choose to manipulate the nature of the research.

Teachers' participation and interaction in the program were observed by taking field notes after each implementation. Teachers at a private school reorganized an application they chose and implemented it with 7th-grade students, and this study lasted two weeks. Observations were made by participating in the implementation with the students.

2.4.1 Semi-structured interviews

After the end of the PG program (2 weeks later), Semi-structured interviews were conducted with the teachers. The interviews lasted 30-40 minutes on average and were conducted in Turkish, the native language of the participants. The reason for not conducting interviews immediately after the practices was to reveal what they had learned about EDP in case time had passed instead of reflecting on what they had learned directly at the end of the PG program. Semi-structured interview questions were arranged at the beginning of the study to be compatible with IMPG domains.

Table 2.8 Interview questions linked with the IMPG domains

Interview Questions	Relationships between the domains
Have you been trained about EDP before?	Personal Domain (before)
What did the participants do while putting what they learned into practice (observation notes)	Domain of Practice
Can you briefly describe what you do in practice?	
Which activities do you think were the most successful, which was the least successful and which contributed the most?	
Can you tell us about the strengths and weaknesses of the applications?	
How did you contribute to group work?	
Would it be more productive online or face-to-face? Why?	
Would you consider implementing/experiencing EDP in your classroom? How?	Domain of Consequences
What are your limitations/support points for implementing EDP in the school environment?	
When you apply EDP in the classroom (when ideal conditions are provided), how do you think it will contribute to students?	
Can EDP be integrated into your own branch? How?	
What do you think the role of the teacher should be in EDP?	
What does EDP aim for in general? What have you learned?	Personal Domain (after)
What are the similarities and differences between EDP and Inquiry based?	
What steps come to your mind when you think of EDP? What kind of a process?	
What did you experience from the practices?	External Domain
Did you learn anything from other team members?	
What did you find different and interesting?	
General criticism (did it meet expectations?)	
Can you tell us about the aspects of the apps that you find interesting?	
Do you think EDP activities are necessary?	
How was the student response?	IN-CLASS Domain of Practice
Did the students actively participate in the application?	
What difficulties/comforts did the students experience?	
What difficulties/conveniences did you encounter while practicing with students in the classroom?	IN-CLASS Domain of Consequences
What do you think the students gained in the application you made in the classroom?	
Was there a change in your initial opinions?	
What the participants did while putting what they learned and developed into practice in the classroom (observation notes)	IN-CLASS External Domain

Interview questions were categorized by the IMPG domains in Table 2.8. In this way, it was aimed to understand whether each teacher professional growth holistically.

2.4.2 Observation notes

In participant observation studies, researchers participate in the situation or setting they are observing. When a researcher chooses the role of participant-observer, he or she fully participates in the activities of the group being studied but also makes it clear that he or she is conducting research. In this study, the participants were aware of the researcher's role as a researcher and participated in the EDP and classroom implementation process; the researcher guided the teachers and created the PG program (Fraenkel et al., 2012).

2.4.3 Teachers' worksheets/presentations

The interview questions of Friedrichsen et al. compatible with IMPG domains were revised and transformed into interview questions covering the engineering design process through an environment-themed STEM module. Observation notes were taken throughout the program as a secondary data source. The study was completed with semi-structured personal interviews aligned with IMPG domains as the primary data source. Public school teachers' documents in which they shared the results of all three implementations as a group and private school teachers' pictures of their in-class implementations were collected as data revealing how they experienced EDP.

2.5 Data Analysis

The amalgamation of deductive and inductive analysis approaches in educational research provides a robust framework for comprehending and interpreting intricate phenomena associated with teachers' professional growth. While inductive analysis focuses on drawing patterns, themes, or hypotheses directly from the data itself, deductive analysis applies pre-existing theories or frameworks to guide the examination of data. Researchers can gain a deeper grasp of the variables affecting teachers' professional growth and the outcomes of various treatments thanks to this integration (Johnson & Stake, 1996; Lewis, 2015).

In the analysis with the deductive approach section, the researcher created categories associated with each of the four domains of IMPG. For example, "teachers' level of knowledge about EDP" was categorized as related to the personal domain by subdividing that category as "before" and "after" PG.

For the domain of Practice, the 12 indicators in the quality framework for K-12 engineering education developed by T. J. Moore et al. (2014) were used in the reflective category of this domain as they are related to professional experiences and used as a framework in the process of designing activities. Therefore, "levels of quality k-12 engineering education" was used as a category in the form of teacher experiences during the EDP and in-class implementations. Similarly, "Teachers' experiences (context or skills) specific to the activities," which was considered as an external source of information, was categorized, while "Students' experiences (context or skills) specific to the activities," which was considered as an external source of stimulus, formed a separate category. Finally, for the Consequence, which is another domain of the IMPG model, lesson plans or implementation plans are categorized as "possible instructional plans" and "expected learning outcomes for students" in case teachers intend to implement it as a classroom activity after PG. For the completed in-class implementation, it is categorized as an "applied instructional plan," and "evaluated student learning outcomes," which are the other categories related to this domain.

In the part of the analysis with an inductive approach, the data set (semi-structured interviews, teachers' worksheets/presentations, observation notes) was read from beginning to end. Data were analyzed firstly by associating the interview questions with the IMPG domains. Open coding was used, and equivalent items from the data sets were given the same code. Codes were created under the relevant category by considering the common expressions in the data, the qualities of the explanations, whether the data reflected the indicators or not, the similarities, differences, and preferences in the phrases, which point the observation notes supported, which aspects the teachers' presentations or worksheets reflected. For example, the responses about teachers' knowledge of EDP in the Personal domain were either very shallow or short or very general and informative. Therefore, the terms well-informed or ill-informed were preferred. If there was no explanation about the subject, the code "no information" was used.

For the Domain of Practice, the Quality K-12 Engineering Education framework (T. J. Moore et al., 2014) was utilized specifically designed for all K-12 students. This framework comprehensively covers the entire Engineering Design Process (EDP) and comprises 12 indicators that address various engineering fields and tasks. Beyond its role in data analysis, the framework played a crucial role in developing the STEM module dedicated to EDP.

The analysis within the Domain of Practice involved an examination of the 12 indicators to assess the degree to which teachers engage in engineering activities and apply engineering design principles during both the EDP and classroom implementations. To categorize the "Quality K-12 Engineering Education," four different codes were established based on the frequency of occurrence of the 12 indicators. Therefore, among the 12 indicators, "mostly" was used for explanations and observation notes reflecting more than nine indicators in the data set, "often" for more than six indicators, "sometimes" for six or less than six indicators, and "rarely" for three or less than three indicators.

For the category "Teachers' disciplinary experience of the activities," which is related to the External domain, the code "relevant" was used because meaningful experiences and evaluations of the activity in terms of both context or skills were considered. The code "irrelevant" was used if the experiences or evaluations of the activities were not relevant in terms of context or skills. When assessing teachers' professional growth, the "learning environment preferences" category, encompassing online or face-to-face settings, was coded. However, it wasn't factored into the analysis of teachers' professional growth levels as it's associated with their personal orientation within the domain. The relationship between teachers' preferences for their own learning environment and their students' learning environment is discussed separately.

For the "Possible Lesson Plan" category related to the Domain of Consequence, "expert" or "novice" codes were determined. Teachers' lesson plans were coded as "expert" if they were detailed, addressed certain basic steps related to EDP, or included a different idea unique to them, and if not, they were coded as "novice." For the category "Expected Learning Outcomes for Students," codes reflecting at least two developmental characteristics (cognitive/affective/social) were considered. As can be seen in Table 2.3, the coding for whichever outcome it is

related to is marked on the table. When the data set was analyzed using open coding, explanations about problem-solving, reasoning, analytical thinking, identifying problems, learning disciplinary issues, brainstorming, research, and trial, and error were considered as cognitive outcomes. For effective outcomes, expressions such as attention to the environmental issue, looking more solution-oriented, awareness, interest, and excitement were listed. For social outcomes, the words group work, communication, and working in cooperation were evaluated.



Table 2.9 Professional growth of teachers in terms of EDP implementation and in-class implementation

	PERSONAL						PRACTICE				EXTERNAL				CONSEQUENCE					
EDP IMPLEMENTATION	Knowledge about EDP						Levels of Quality K-12 Engineering Edu. for teachers				Teachers' Disciplinary experience related to activities		Teachers' preference for possible learning environments in-class		Likely Teaching Plan		Expected Learning outcomes for students			
Participants	Before			After																
	well-informed	ill-informed	no info.	well-informed	ill-informed	no info.	mostly	often	sometimes	rarely	relevant	irrelevant	online	in face	expert	novice	cognitive	affective	social	
P1																				
P2																				
P3																				
P4																				
P5																				
P6																				
P7																				
P8																				
P9																				
P10																				
IN-CLASS IMPLEMENTATION							Levels of Quality K-12 Engineering Edu. for students				Levels of Students' Disciplinary experience		Students' learning environment		Applied Teaching Plan		Evaluated Learning outcomes for students			

The categories and codes obtained from the deductive and inductive analyses were combined to find a common point. For this purpose, as a result of coding the data sets under the relevant category, which code belongs to which participant was created by preparing a table and using color codes in Table 2.3. By looking at the frequency of the positive expressions associated with each category, the level of professional growth of teachers as "sophisticated," "eager," "average," and "naive" were created based on the data. In that way, the situation/category of teachers' professional growth did not arise deductively but rather as the outcome of inductive analysis.

In the frequency calculation based on these findings, P3 and P6, "sophisticated," P1, P2, and P10, "eager," P9 and P10, "average," and finally, P4, P5, and P7 "naive" emerged as four different teachers' Professional growth level. The levels of meaning and details will be discussed under each profile in the conclusion part, as you can see in Table 2.4. Participants 3 and 4 can be given as examples of determining professional growth levels with deductive analysis. In coding teachers' professional growth as "sophisticated," the frequency of the following situations was examined. When the available data was analyzed for "knowledge about EDP," which is the category associated with the personal domain, it was coded as "well-informed. When the Domain of Practice was analyzed; it was coded as "mostly" or "sometimes," reflecting the frequency of the most among the 12 indicators. For the category "Teachers' disciplinary experience related to the activities," which is related to the External Domain, it was coded as "relevant." The code "expert" was identified for the category "Likely Teaching Plan," which is related to the Domain of Consequence. In the same category, codes reflecting at least two developmental characteristics (cognitive/affective/social) were considered for the category "Expected Learning Outcomes for Students."

For all codes, evidence from the data set was available for P3, who has a "sophisticated" level of professional growth, but much less for P4, who has a "naïve" level of professional growth. A more concrete example of this can be seen in the difference between the answers of both participants to the question "Would they like to apply these studies when they have the opportunity?" and "If so, how would they apply them?".

It is understood that P3 answered this question, which is evaluated under the category of "Teaching plan" as "expert" in a more informative way.

"The grade level of the students is also important. It may be a little difficult to make the 5th-6th graders think about these topics, but I think the 8th graders can grasp them more easily. But right now, when we give these activities to 5-6s, they can probably do their numerical operations. They will not have trouble in that sense. They do it comfortably, especially in Excel. I think that if we make the children do each of these in a week or two, that is if we make them do it in 4 hours or 6 hours, they can understand much more easily. We can make a connection with life and attract students' attention by giving examples from daily life. After all, children pay more attention when they see these things. After all, we can think of the point we are trying to reach in the field of engineering as low energy and high efficiency. In the computer field, what we are trying to achieve is less code and reaching the targeted result."

On the other hand, it was understood that P4 gave a "novice" explanation in this regard.

"There is a shortage of time in the current system. It can be implemented with selected students in an exercise style, such as a weekly study after school or on weekends. But first, we need to be able to explain the logic of the work we will do, this Engineering thing, to the children. Otherwise, if we start directly, as we do as teachers, the children look at it; they cannot make any direct comments, and they have no idea. It is something they will encounter for the first time. Explaining that such a thing exists and how it should be thought, I think we can then apply them. I think it is very difficult with every student in a classroom environment."

Even though P4 said that she would apply it in class, it is understood that her answer on how it can be done is closer to traditional learning methods and that she sees the teacher more in the role of explaining. That's why her explanation from the data was coded as a novice under the category of "Likely Teaching Plan," which is related to the Domain of Consequence.

In-class implementation was conducted jointly by P9 and P10, and the data set obtained was also evaluated under related categories, as you can see in Table 2.3. For example, instead of the "Likely Teaching Plan" category, it was expressed as "Applied Teaching Plan." Similarly, the individual evaluations of the teachers in the semi-structured interview conducted after the in-class implementation and the observation notes taken by the researcher during the in-class implementation were used as data sets. Since the teachers' knowledge about the EDP was obtained at the

end of the processed implementation, the “knowledge about EDP” category was not included for the in-class implementation. Nevertheless, all other categories justify the domain of practice, external domain, and domain of consequence, the similarities or differences between the codes reflecting their professional growth during the EDP implementation. The codes received from the in-class implementation were examined in the conclusion and discussion section, together with the reasons.



3

FINDINGS

In this section, the findings are divided into two headings, as in Table 2.3, shown earlier: EDP and in-class implementation. In the EDP implementations section, for all the categories associated with IMPG domains, it was revealed how the codes were created by making use of particular datasets.

While all teachers participated in the EDP practices, only P9 and P10, who work in private schools, conducted the classroom practice. The aim was to examine the professional growth of these two teachers during the EDP implementation process and classroom practice by analyzing the data sets obtained in the context of in-class implementation. When teachers contribute to each other's development, when they reflect on what they have learned, and when they apply their professional growth in an authentic way to the classroom, in short, it is important to understand what kind of findings emerge in terms of both EDP and in-class implementation.

The study concludes by evaluating teachers' professional growth based on the IMPG domains, revealing distinct characteristics such as "sophisticated," "eager," "average," and "naive" through the analysis of positive statements in Table 2.4. Participants like P1, P2, P3, P6, P9, and P10 showed improvement in their explanations about EDP in the Personal Domain after PD. In the Domain of Practice, P1, P2, P3, P6, P6, P9, and P10 predominantly had positive coding for the 12 indicators. P1, P2, P3, P6, P8, P9, and P10 were deemed "relevant" in their explanations related to the External Domain. In the Domain of Consequence, P3, P5, P6, P8, and P10 demonstrated expert level for the teaching plan, and P1, P2, P3, and P6 covered at least two student outcomes. In this way, the frequency calculation resulted in four teacher profiles: "sophisticated" (P3 and P6), "eager" (P1, P2, and P10), "average" (P8 and P9), and "naive" (P4, P5, and P7). The study emphasizes the dynamic character of teachers' professional growth by highlighting both obstacles and advancements.

Table 3.1 Levels of teachers' PG for domains based on frequency calculation

Levels of Teachers' professional growth	For Personal Domain- under the category "Knowledge about EDP" participant has code as "well-informed"	For Domain of Practice under the category "Levels of Quality K-12 Engineering Education for teachers" participant has code "mostly" or "sometimes"	For External Domain under the category "Teachers' Disciplinary Experience Related to Activities" participant has code "relevant"	For Domain of Consequence under the category "Likely Teaching Plan" participant has code "expert"	For Domain of Consequence under the category "expected learning outcomes for students" participant has min 2 codes "cognitive", "affective" "social"
Sophisticated	P3,P6	P3,P6	P3,P6	P3,P6	P3,P6
Eager	P1,P2, P10	P1,P2, P10	P1,P2, P10	P10	P1,P2
Average	P9		P9	P8	P8
Naive				P5	

In the frequency calculation based on these findings, P3 and P6, "sophisticated," P1, P2, and P10, "eager," P8 and P9, "average," and finally, P4, P5, and P7, "naive" emerged as four different teachers' Professional growth level. The levels will be discussed under each profile.

- **Sophisticated**

The dictionary defines "Sophisticated" as "(of a person) able to understand difficult or complicated ideas" (Oxford University Press, 2023). P3 and P6 have codes that positively express teachers' professional growth in all subcategories of IMPG domains. This means that in the personal domain category, they have well-informed statements about EDP knowledge; in the Domain of Practice, P3 often and P6 mostly are labeled as such because they have statements reflecting the important part of the 12 indicators. For the External Domain, they were coded as relevant based on whether their explanations for their experiences in terms of context or skills were related to the activities. In the Domain of Consequence, there were expert explanations to the question of how they would design such a study if they

were to implement it in their classes. Moreover, in student outcomes, P3 made explanations for cognitive, affective, and social, while P6 made explanations for cognitive and affective. Therefore, since both participants had reflective characteristics in line with the above definition, their professional growth was characterized as "sophisticated."

- **Eager**

When the dictionary meaning of "Eager" is searched, "very interested and excited by something that is going to happen or about something that you want to do" definition was seen in Oxford University Press, 2023). P1, P2, and P10 have positive codes in categories related to almost all domains, just like the participants characterized as "sophisticated." However, in the "Likely Teaching Plan" category related to the Domain of Consequence, P1 and P2 described a "novice" lesson plan. P10 mentioned only one cognitive outcome in the same domain but in the category of "expected learning outcomes for students." Therefore, it can be said that although these 3 participants have come a long way in their professional growth, as is stated in the dictionary definition, it can be said that there is a need for learning and development in the context of the Domain of Consequence. For this reason, it was deemed appropriate to characterize the professional growth of the participants as "eager."

- **Average**

"Average" is close in meaning to moderate and reasonable and is defined as follows: "acceptable and appropriate in a particular situation" (Oxford University Press, 2023). The professional growth of P8 and P9 was characterized as "average" according to the codes they received from different categories. For example, P8 has an "ill-informed" explanation about EDP knowledge for Personal Domain, while P9 has a "well-informed" explanation. Similarly, for the External Domain, the relationship of their experiences with activities is "irrelevant" for P8 while it is "relevant" for P9. As an example of the opposite, in Domain of Consequence, P8 mentioned experimental and "cognitive and social" outcomes for both likely lesson plans and students' learning outcomes, while P9 had a novice explanation and talked only about "cognitive" outcomes. In the Domain of Practice comparison, P8 coded "rarely," reflecting very few of the 12 indicators, while P9 coded sometimes.

Therefore, when we consider that the IMPG domains support each other in a holistic way, the participants who showed positive professional growth through different domains were judged to be "average" when considered as a whole.

- **Naive**

"The meaning of the "Naive" is defined with the following phrases "(of a person or action) not showing enough knowledge, good judgment or experience of life" (Oxford University Press, 2023). P5 and P7 coded "sometimes" reflecting a significant part of the 12 indicators in terms of Domain of Practice. Differently, P5 had an "expert" explanation for "likely lesson plan" in relation to Domain of Consequence, while P7 mentioned only one social outcome in relation to students' outcomes. It is noteworthy that the other two participants (P4 and P5) had no explanation for student outcomes. P4 has no code with a positive meaning in all categories related to IMPG domains for professional growth. In short, these three participants were characterized as "naive," which is quite compatible with the dictionary meaning, as they had findings reflecting very few codes in terms of their professional growth.

Each of the research questions pertaining to the IMPG domains and their corresponding findings are explicated below.

3.1 What is the knowledge level of teachers in terms of EDP (personal domain)?

In the data analysis process, before the EDP implementation, teachers were first asked whether they had received any training on EDP. The teachers were then asked a few questions for a brief overview of what they had learned about EDP, including its goals, nature, and stages. In this context, the category "knowledge about EDP" was disclosed by their answers, which provided an answer to the first research question linked with the personal domain.

3.1.1 Knowledge about EDP

The change in the knowledge level of the participants constitutes the personal domain of this study. As can be seen in Table 3.1, when we look at the data reflecting what they know about EDP, it is seen that the teachers except P9 and P10 had no idea before PG, and these two teachers briefly stated that they received

training about STEM and that it could be related to this. These statements were coded as "ill-informed" because they were insufficient. As an example, P10 used the following statements:

"We made a bridge out of pasta as a STEM activity at the university. I don't know the engineering design process, but I wonder what it is."

On the other hand, it was understood that 6 participants (P1, P2, P3, P6, P9, P10) had the code "well-informed" in their explanations about EDP after PG, while the other 4 participants had "ill-informed" explanations. For example, P2 has highly informative and explanatory statements in this regard.

"The first thing that came to my mind was an iterative process because it's really important to turn back the section what you want to change. First, there needs to be a problem related to daily life, and we need to do research. Research, identifying the problem, determining the criteria, developing, etc. For example, in the field of energy, the depletion of our resources and the fact that people direct us to renewable energy sources with science and technological developments. After identifying the problem, a team can develop solutions by generating different ideas. I can say that a study can be created for the optimum use of resources for the solution, how we can solve it in the best way with the materials we have or the data we have."

In an interview with teachers before the PG program of this study, the participant (P10) said that she had participated in STEM training and that they tried to make a bridge out of pasta. Another participant stated that under the name STEM Education, it was related to robotic coding, and there were applications such as using a 3D printer and building circuits in Arduino with Thinker Makey Makey materials. The literature confirms this point and states that robotic coding educational tools are associated with STEM education. (Chung, Cartwright & DeRose, 2017; Tuluri, 2017) In fact, it was observed that the teachers tried to explain that STEM education does not only include robotic coding or project-based learning. Another participant (P9) stated that STEM is popular, but she thinks that it is mostly used for advertising purposes, which shows that STEM education is not done in the right way.

3.2 How do the teachers assume the engineering role and reflect engineering practices during the EDP and classroom implementations (domain of practice)?

EDP implementation and the in-class implementation were created to address the research question about the Domain of Practice. Semi-structured interview questions that were created separately for each implementation were examined under these headings. Observations were made in both implementations during the process, and the notes made were meant to corroborate the findings. The interview responses and observation notes were analyzed according to the indicators in the "Framework for Quality K-12 Engineering Education" developed by T. J. Moore et al. (2014). In this context, separate headings were created for three different activities completed during the EDP implementation. Teachers' presentations/worksheets are presented here, together with observation notes. In this approach, it became clear that the results were corroborated by the interview questions as well as other data-gathering instruments.

3.2.1 EDP Implementation

3.2.1.1 Quality K-12 Engineering Education

As mentioned in the theoretical framework section, the "Framework for Quality K-12 Engineering Education" developed by T. J. Moore et al. (2014) consists of 12 indicators. All the actions that serve the professional growth of teachers during PG are related to the Domain of Practice. Since the EDP activities were prepared by making use of this framework and the 12 indicators mentioned in the evaluation of teachers' practices reflect a quality engineering education, teachers' practices were analyzed in the context of a deductive analysis approach. Since the EDP activities were prepared using this framework and the 12 indicators specified in the evaluation of teachers' practices reflect a quality engineering education, teachers' practices were analyzed in the context of a deductive analysis approach. For this purpose, a matrix table was created, and each participant's semi-structured interview responses or worksheets/presentations and observation notes during group work were taken into consideration. The data considered to be evidence for each indicator was entered into the matrix table as "+" if available and "-" if not. By looking at the frequency of those with "+" in the table, teachers with similar frequency were included in the same category. Therefore, among the 12 indicators, "mostly" was used for participants reflecting more than nine indicators in the data set, "often" for more than six indicators, "sometimes" for six or less than six indicators, and "rarely" for three or less than three indicators.

Table 3.2 For each participants evaluation of 12 indicators based on framework for quality k-12 engineering education

	P O D	POD PB	POD PI	POD TE	SE M	E- Thin k	C E E	E- Tool s	I S I	Eth ics	Te am	Comm Engr
P1	+	+	+	+	+	-	-	+	-	-	+	+
P2	+	+	+	+	-	+	+	+	-	+	+	+
P3	-	-	-	+	-	+	+	-	+	+	+	+
P4	+	-	-	-	-	+	-	-	-	-	-	+
P5	+	-	-	-	-	-	+	+	-	+	-	+
P6	+	+	+	+	+	-	+	+	-	+	+	+
P7	+	-	-	-	-	-	+	-	-	-	+	+
P8	-	-	-	-	-	-	+	-	-	-	+	+
P9	+	+	+	+	-	-	-	-	-	-	+	+
P10	+	+	+	+	-	-	+	+	-	-	+	+
IN- CLASS	+	+	+	+	+	-	-	-	-	-	+	+

- **Process of Design (POD)**

This indicator refers to the participants' implementation of the basic steps of EDP: readiness, planning, evaluating, review, and development through real-life problems, and emphasizes the iterative nature of engineering. Therefore, the statements made by eight teachers (P1, P2, P4, P5, P6, P7, P9, P10) about the PG activities during the semi-structured interview are labeled as "+" as they constitute evidence for this indicator. For example, P10 reflects this indicator, and its statement is as follows.

"In the EDP process, I can think of basic issues such as empathizing by putting yourself in the customer's shoes, defining the problem, perhaps observing in the field, generating

ideas, prototyping, testing, and returning to the necessary stage if the desired solution is not achieved.”

The participant's mention of the key stages of EDP, and in particular the phrase "back to the required stage," is explicit evidence of the iterative nature of engineering. P1 shared his ideas in the words below.

“Wind rose activity can be an example for EDP. I better understood the historical change in wind turbine design and its current structure. It was a process of using the wind atlas and calculating the average wind speed of the given region, finding out how many turbines can meet the customer's energy demand, and calculating the budget. Of course, we didn't think of all this at the same time. Just when we realized that we had made a calculation and reached the result, we realized that we did not take other things into account and turned back to the part that we had to change. Sometimes we did research, and sometimes we did the calculation again.”

The participant mentioned some basic stages of EDP, and the phrase "returning to the necessary stage" is evidence of the iterative nature of engineering.

- **Problem and Background (POD-PB)**

This indicator, which talks about the need to identify constraints and criteria by analyzing an open-ended daily life problem and determining what needs to be learned to build on existing knowledge, is mentioned in the statements of 5 participants (P1, P2, P6, P9, P10).

“All the applications were interesting but let me briefly summarize one of them. We had an apartment building in the solar energy study. We were thinking about how much energy we could provide, how much money we would pay, and how much solar energy we would provide on the system where we could make our annual energy level in the apartment building. There was an accepted cost for this; we were calculating the solar panels and the time it took to pay for them. We used the solar atlas for this and used real data. We thought of solutions to shorten the payback period for customer satisfaction.”

As it is understood, the P9 talked about how they analyze the problem situation, how they determine their needs, and how they try to solve them. This statement reflects this indicator because POD-PB emphasizes the definition of the problem more.

- **Plan and Implement (POD-PI)**

The same 5 participants (P1, P2, P6, P9, P10) had expressions that were reflective in this indicator as in POD-PB. This indicator requires more than one solution

proposal for the problem situation, considering the identified criteria. This makes brainstorming and developing some action stages important. The explanation of P2 is given below for illustration purposes.

“What I realized in the activities were the different interpretations of my friends. Of course, Like every time, they looked at the problem from very interesting perspectives. I mean, after someone said something very logical, the other one said something completely different, saying, " No, it's like that." So, the fact that there is not one truth, or one right thing was particularly striking to me.”

As it can be understood from here, the participant thought that the teachers who brainstormed during the group work found different ideas and solutions to be "different interpretations of my friends."

- **Test and Evaluate (POD-TE)**

In addition to the same 5 participants (P1, P2, P6, P9, P10), P3 also made a reflective statement in this part. The only way to know whether an idea, solution, or model works is to meet the test and evaluation indicators. Participants who thought this was important have mentioned this indicator in their interviews.

“This was a job that considered both sides and tried to make our lives easier. That's why we did different trials, gave different numbers, expanded the area, reduced the square meter, and enlarged it. We evaluated all the alternatives that we would lose less or make more profit and that the user would be satisfied.”

In addition, it was observed that the PG participants (P3, P4, P5, P7) as a group, implemented three different activities by taking advantage of the teachers' learning about the engineering design process and inquiry-based learning and that they did not limit themselves to a single solution because they might be able to understand the iterative nature of engineering, for example, in the activity related to the solar panel, a group preferred to produce fresh solutions by adding half an inch to the roof area given to them with a different approach, although they found a suitable solution as a result of their calculations.

Similarly, it was noted during implementation that teachers P9 and P10 leveraged the iterative nature of engineering to provide several proposals rather than sticking to a single one. For example, in the wind turbine application, they realized that they had not considered the transportation costs to build a wind turbine farm in the area

they had chosen and completed their mathematical calculations again, showing that they started to think in multiple ways.

- **Apply Science, Engineering, and Mathematics (SEM)**

This indicator refers to trying to solve the problem situation by utilizing disciplinary knowledge in the EDP process. It was observed that teachers found it useful for students to make mathematical calculations and create graphs or tables with inquiry-based activities before EDP. Students learning about recycling and renewable energy sources from science concepts were found useful in solving the problem situation in activities about EDP by teachers. Also, it was observed that teachers actively participated in the inquiry-based part. This is because, as this indication suggests, disciplinary knowledge can be used during an engineering education, or a disciplinary course can be integrated into the EDP problem. Among the participants, only P1 and P6 made statements reflecting this indicator. For example, P1 states that students might learn them during the activities for utilizing knowledge. From this, it is possible to understand that the students' need to know is important rather than giving direct information.

Similarly, P6 talked about how scientific knowledge and engineering are intertwined and gave an example of a topic in mathematics that they used to solve a problem.

If we were to start directly with EDP, I think we would be surprised. We wouldn't really know what to do. But after gaining knowledge, adaptation is easier. Moreover, this information is not given directly by the teacher, but the student learns through activities. In other words, while one is looking for answers to questions, the other, EDP, seems to find a solution to the problem.

Similarly, P6 talked about how scientific knowledge and engineering are intertwined and gave an example of a topic in mathematics that they used to solve a problem.

In research and inquiry, let's say only a solution can be put forward, but when you say engineering, it can be thought of as an artifact. Something comes out, but in research, when you say inquiry-based, we research, we question. For example, during the EDP, we tried to find the most ideal option by using the ratio-proportion in mathematics. For this reason, in my opinion, engineering is definitely not separate from scientific knowledge. It's as if engineering develops tools to facilitate the discovery of scientific knowledge, while scientific knowledge serves to develop whatever the product or model is during EDP.

In addition to these, during EDP activities, it was observed that teachers (P3, P6, P8) used the knowledge that plastics have different codes in the stop-motion video, making it the subject of the video they prepared as a group. This is a supportive finding showing that teachers use what they have learned in EDP activities.

- **Engineering Thinking (EThinking)**

The Thinking indicator refers to learning from mistakes and developing different thinking skills. Metacognitive, imaginative, reflective, and analytical thinking can be seen among the mentioned thinking skills. The participants with statements reflecting this indicator are P2, P3, and P4. P3 emphasized trial and error more in his statement on this subject.

“In the study, we first guessed whether we should do it like this. Then, we tried to see the results directly from the numerical data part of the work with trial and error. We definitely tried to find the most appropriate result.”

P4, on the other hand, mentioned reflective thinking in her statements.

“I try to think like different engineers. You know, we used to see a machine or a wind turbine we looked at, but we were looking at it; now I wonder about the working principle; I look more questioning by saying why they built this here.”

- **Conceptions of Engineers and Engineering (CEE)**

There are 7 participants (P2, P3, P5, P6, P6, P7, P8) with statements reflecting this indicator that talk about the role of engineers, different engineering fields, and the importance of gaining an awareness of this field. It was observed that they actively participated in the inter-teacher discussion about engineering and its role at the beginning of the PG, and when they were asked to imagine an engineer, different engineering fields were clearly mentioned.

P3, who emphasized the importance of an interdisciplinary approach, shared the notes of the interview with the engineers together with his students. The participant explained the CEE indicator quite clearly and clarified the role of engineering and how different engineering fields work together.

The engineering design process is ultimately aimed at the benefit of people. They are trying to find out what the need is. How to solve in the most appropriate way. Different engineering fields work together. One field is not enough. Inventing tools is not enough to design them. Recently, engineers came to our school and introduced their fields to the students. they said, "We didn't do this only as a computer engineer; we are working here

together with an electrical and electronics engineer." None of them actually seem to work with their own field alone, so I realized that there are other engineering disciplines that work with each other.

P7, which describes the awareness of engineering rather than the role of engineers, has statements that reflect this indicator in a unique way.

"I don't have what is called a commercial mind anyway. I hadn't thought about such things, to be honest. Calculating the cost of something and the energy supply that it will bring along with the cost, there are really a lot of calculations behind the scenes. Many things are considered, and thousands of factors are considered in terms of engineering. Honestly, I became aware of these things."

- **Engineering Tools (ETool)**

The ETools indicator addresses the techniques used and the skills required, as well as the effective utilization of the various tools available. 4 participants (P1, P2, P5, P6) mentioned this indicator in the interviews. For example, P10 indicated that the use of Excell can be convenient in these activities by touching on a few points.

"It is more permanent to give the basic information and do something like these activities rather than just explaining the ratio and proportion as a lesson. The ratio can be used in Excel in applications. We can sort, filter, do it from a to z or z to a, or we can use it for things like red and green or show those that exceed or exceed the price, add, subtract, divide, and take the average, depending on what we choose. For example, we use tabulation information; emphasis, background, and foreground are all needed. When making a presentation to the customer, we already need tabulation knowledge, which is a very turning point for us."

- **Issues, Solutions, and Impacts (ISI)**

The only indicator mentioned by only one participant (P3) was ISI, and it is about the importance of looking at the impact of the studies at the sociological, global, and economic scales.

"I mean, there is global warming; we can use solar energy as a renewable energy source. With the EDP project, it was absolutely necessary to present this and see how the public reacted. Did the public or the customer benefit? What is their reaction? Is there positive feedback? If there are complaints, how can we organize them? Are there any points that we have missed? With such opinions, the engineering design process can be updated again."

- **Ethics**

The ethical indicator covers a wide range of issues, such as the most efficient use of natural resources, protection of customer profits, protection of living assets, and legal regulations. There were 4 participants (P2, P3, P5, P6) who mentioned this issue during the interviews. As an example, P5 clarified his ideas about ethical considerations below.

“Depending on the customer's request, I can say that all efforts to satisfy him/her in an environmentally friendly and appropriate way. Making life easier and providing a benefit to the environment is important in this context.”

In addition, in the solar panel study, it was observed that a group (P3, P4, P5, P7) presented the idea of expanding the roof area by half an inch to make more use of the renewable energy source of the sun and to consider the economy of the client. Due to the iterative nature of engineering, P6 stated that there could be legal implications if the roof area were extended by half an inch or that it should be investigated whether it would damage the building foundation. This is an effective example of both the technical approach of engineering and the ethical consideration of the environment, society, and the individual.

- **Teamwork (Team)**

In the interview about teamwork, all participants except P4 and P5 mentioned the advantages of group work. They clearly mentioned the harmony between their groupmates and the fact that they developed solutions by respecting each other's ideas. Although P4 and P5 also took an active role in group work throughout the process, they did not make any statements on this topic. P3 talked about how he and his group members divide their work, respect each other's ideas, and try to find out what is most useful.

“When P1, me, and P8 were together, P1 and I were like in the calculation part of the work. Then we need to add the data we need to subtract; what would happen if we subtracted this from that? Would it be more profitable if we increase this, or would we benefit more from solar energy? How can we save more time, etc... We did a few tests to see which one of the ideas would be more efficient. In the end, we realized that there was not a significant difference and that there could be alternative advantages according to preference. We had done so many operations and, in the end, we found remarkably close numbers again. So, we agreed on the ideal solution. At least we were all able to reach a common point.”

Similarly, P9 told how she and her groupmate looked at things from different directions.

For example, when I was calculating, I was choosing to progress differently, and P10 was, too. If she got it right, it created awareness, and we guided each other's rights and wrongs. We looked at this situation as an inspiration. I was looking in direction a, she was looking in direction b, I saw a, she saw b, we have different characters, and so do the students. Thus, it was important to see each other's characteristics in practice.

- **Communication Related to Engineering (Comm-Engr)**

This indicator with the acronym Comm-Eng refers to the category "Engineering Communication." In each of the three completed EDP activities, the groups were asked to choose a spokesperson and present how much they took into account the criteria and limitations specified in the problem situation, how they made calculations in the process, the advantages and disadvantages of their solutions in a way that everyone could understand. It was observed that teachers who supported their explanations about the solution idea, design, or process with technical calculations preferred to present in diverse ways. As can be seen from the matrix table, all participants have a "+" label in this indicator because the worksheets/presentations of the teachers, which are the product of group work, constitute evidence of this. In the activities, observation notes and images of the worksheets or presentations of the teachers on what they paid more attention to in the process related to EDP, what they did differently, and how they demonstrated it were included. In this way, it can be understood why all participants received a "+" code for the Comm-Engr indicator in the category of "Quality Levels of K-12 Engineering Education for Teachers" within the context of the Domain of Practice for each activity.

- **1st Activity**

The teachers worked in 2 groups with the task of preparing a tender proposal for one of the three different customers who wanted to build a wind turbine farm, setting their criteria and constraints—pictures from the video recordings where the groups put their EDP learning into practice and shared their solutions.

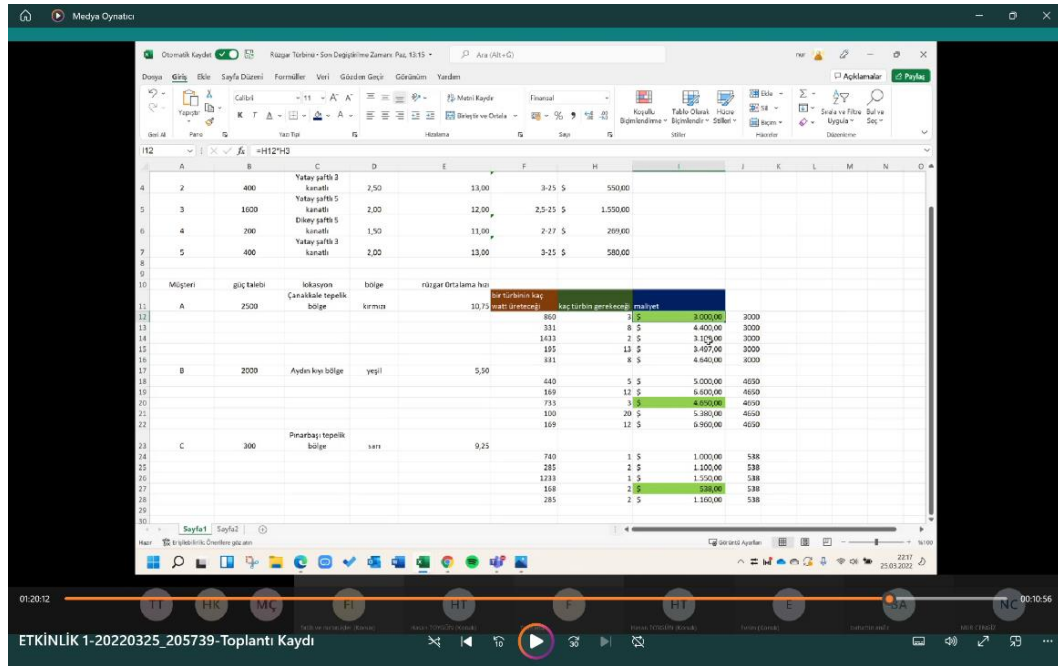


Figure 3.1 Group-1 results for initial EDP implementation

The first group (P1, P4, P5, P7) showed the results of their research on the information they needed for the solution by using the Turkey Wind Atlas and brainstorming within the group by making calculations on Excel and explaining the results through tables as shown in Figure 3.1.

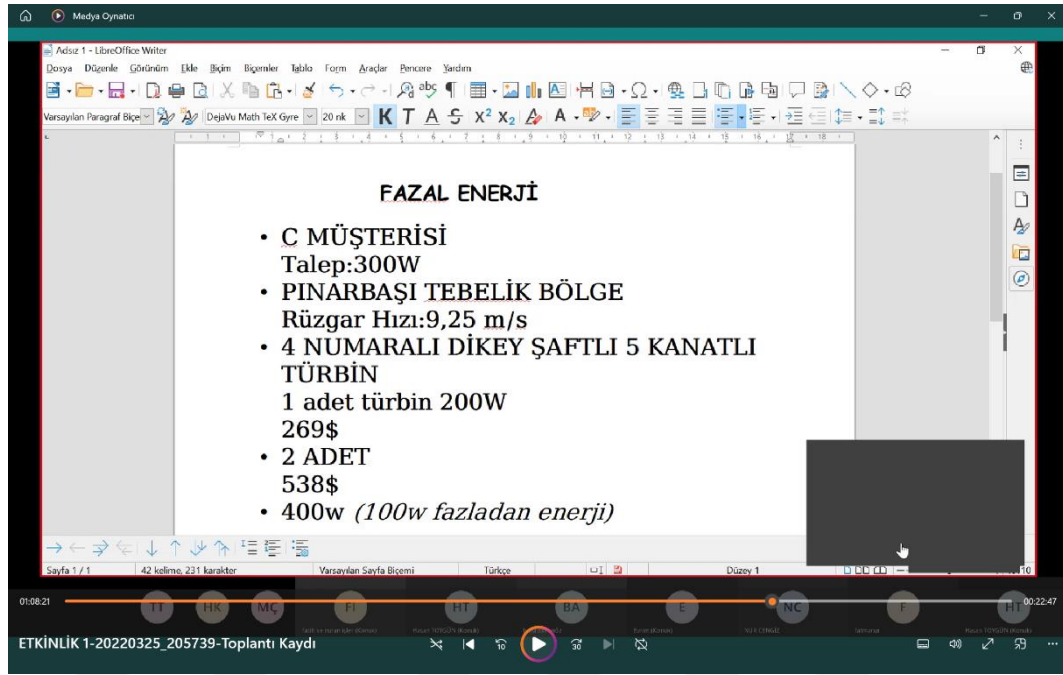


Figure 3.2 Group-2 results for initial EDP implementation

The other group (P2, P3, P6, P8) analyzed a different customer's request for the construction of a wind turbine farm and applied what they learned about EDP and developed solutions like an engineer. Differently, they performed their calculations as a group using pen and paper and presented their results by writing down the details that they considered important on the notepad application of the computer, as seen in Figure 3.2.

○ 2nd Activity

In this study, teachers were divided into three different groups after an inquiry-based activity about recycling plastics used in daily life. They presented their budget estimations and scenarios by preparing a "storyboard" template or a Word document in the Stop motion movie application where they could integrate what they learned into the EDP. While teachers evaluated the effectiveness and relevance of the activities in group interviews, they made different suggestions for budget estimations.

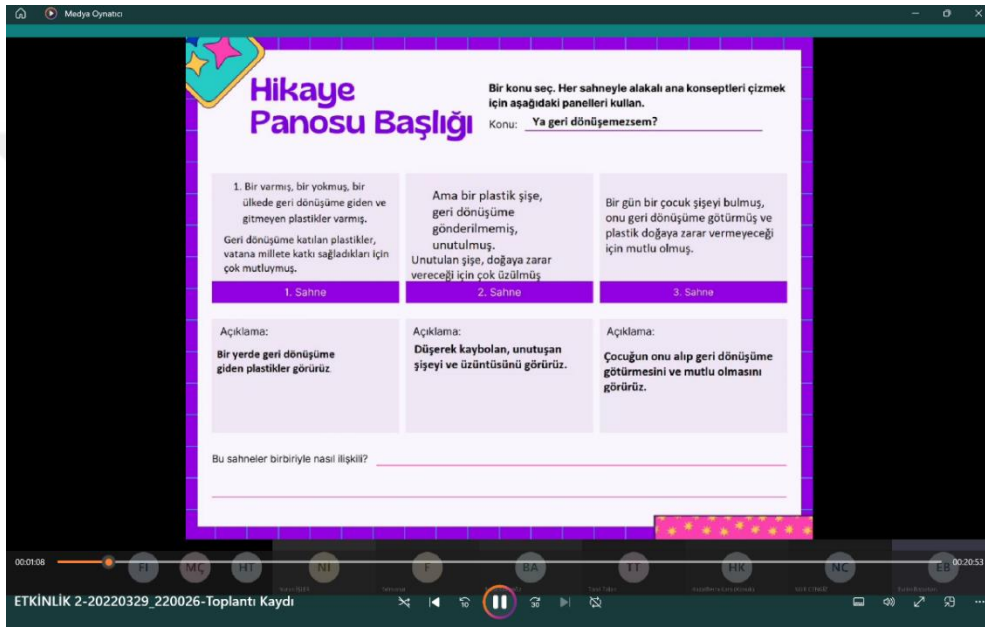


Figure 3.3 Group-1 results for second EDP implimentation

In the first group (P4, P5, P7) scenarios, as shown in Figure 3.3, they mentioned that they would use the picture made by the art teacher together with the students as a background for the first scene in which the plastics that go to recycling are happy. They explained that an unhappy plastic that thinks that it cannot be recycled will be shown with a sad face drawing from the second scene. Afterward, they said that the Lego figure child ended with a happy ending when the child found the plastic and took it to recycle. In the budget planning, the group re-budgeted because the other groups suggested that instead of extra expenses for the camera and lighting, they could make use of cell phones.

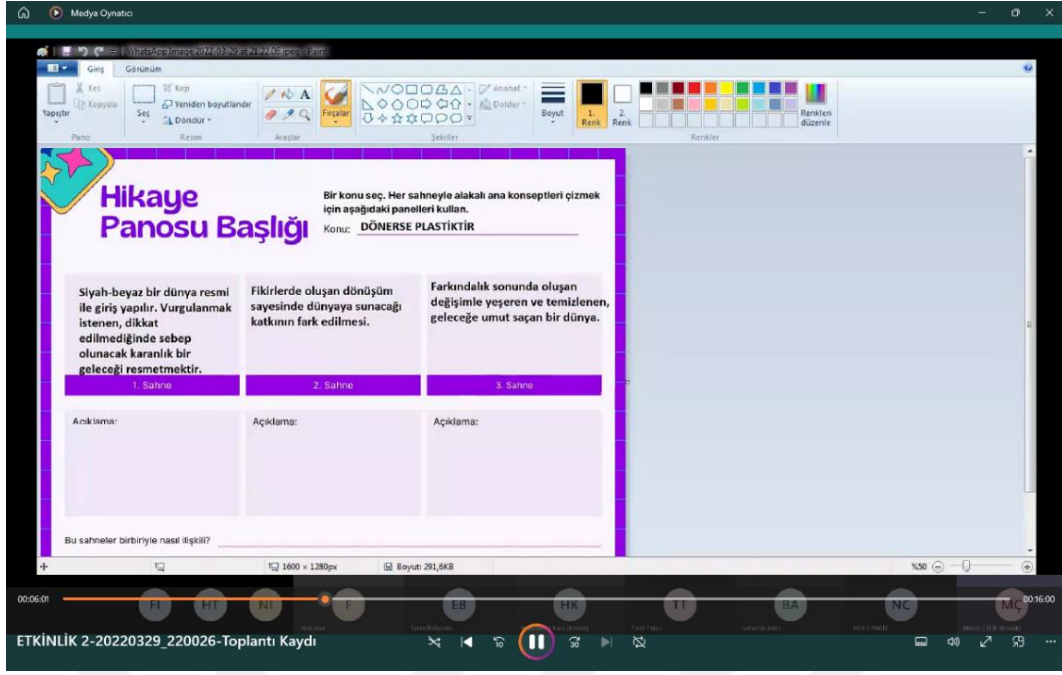


Figure 3.4 Group-2 results for second EDP implementation

Group 2 (P1, P3, PX (excluded participant)) named their scenario, as seen in Figure 3.4, "if it comes back, it is plastic" and said that they would use the world globe in the laboratory in the first scene and place crushed plastic bottles on it. They explained that they would make a simple coloring process to make the globe look dark and that in the 2nd scene, a sanitation worker takes the plastics in the world to recycling. In scene 3rd, they explained that the world slowly turns green with the recycling process. In terms of budget, they gained the appreciation of the other groups in terms of both artistic and economic aspects by saying that they completed the project at an extremely low cost and by using mostly existing products. In accordance with the iterative aspect of EDP, some teachers pointed out how to do the blackout process, that this process should not damage the product, and tried to find ideas for ideal solutions.

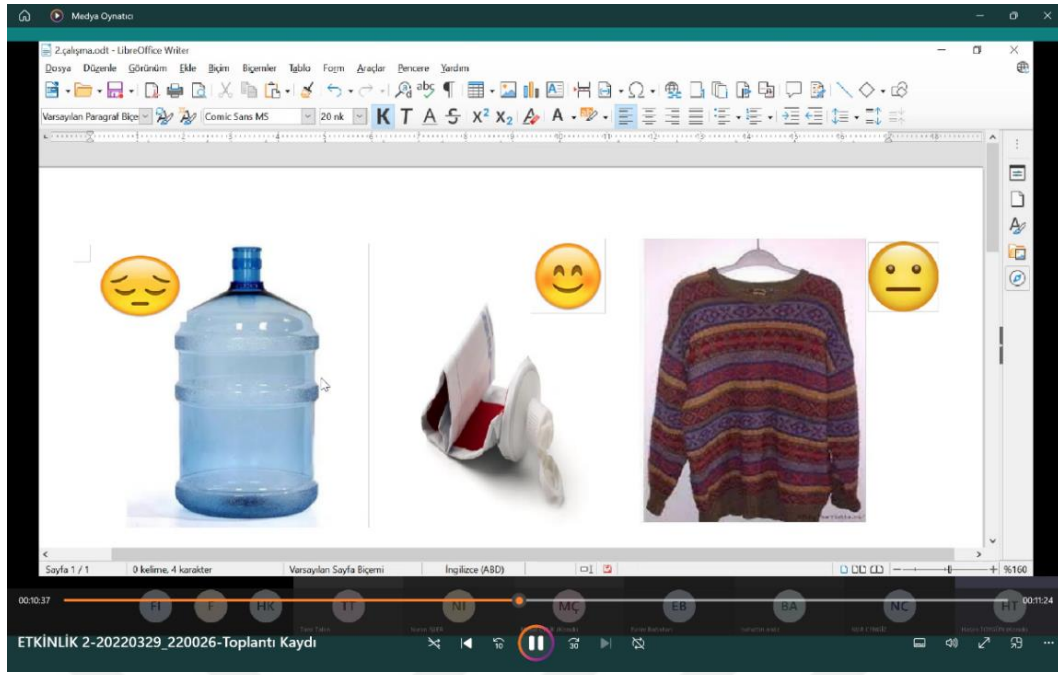


Figure 3.5 Group-3 results for second EDP implementation

As seen in Figure 3.5, Group 3 (P3, P6, P8), unlike the other groups, preferred to explain their stories by adding pictures of the objects they would use in their scenarios to the MS Word document instead of using a storyboard template. They used emojis to reflect the information that some of the materials they learned in the inquiry-based activity could not be recycled and that each of them had a code for this. They checked the code of the plastic carboy in the scenario from the recycling table and found that it could not be recycled. For this, they chose a home environment where the carboy expresses his sadness to other materials. At the end of the story, the father of the house comes with a glass carboy and ends with a happy ending, showing that he now cares about recycling and healthy living. This group, which allocated more budget than the other groups, decided to revise the stage of EDP for alternatives that would reduce their costs.

○ 3rd Activity

In this activity, teachers were asked to prepare recommendations as engineers for a customer who wants to have solar panels installed on their building. For this, the teachers made research and calculations separately for solar panels of different power and cost. They considered the changes in the cost if they used how many of each panel. Also, they calculated the average annual insolation time by looking at

the region where the customer is located from Türkiye's solar atlas. After that they made separate evaluations for the hours when the sun is not in the sky. They also included the kW cost provided by the region's electricity supply grid in their calculations. Details such as how much energy the solar panel would produce if installed and how much of the rest would be supplied from the electricity supply grid to meet the amount of energy demanded were considered during the group work.

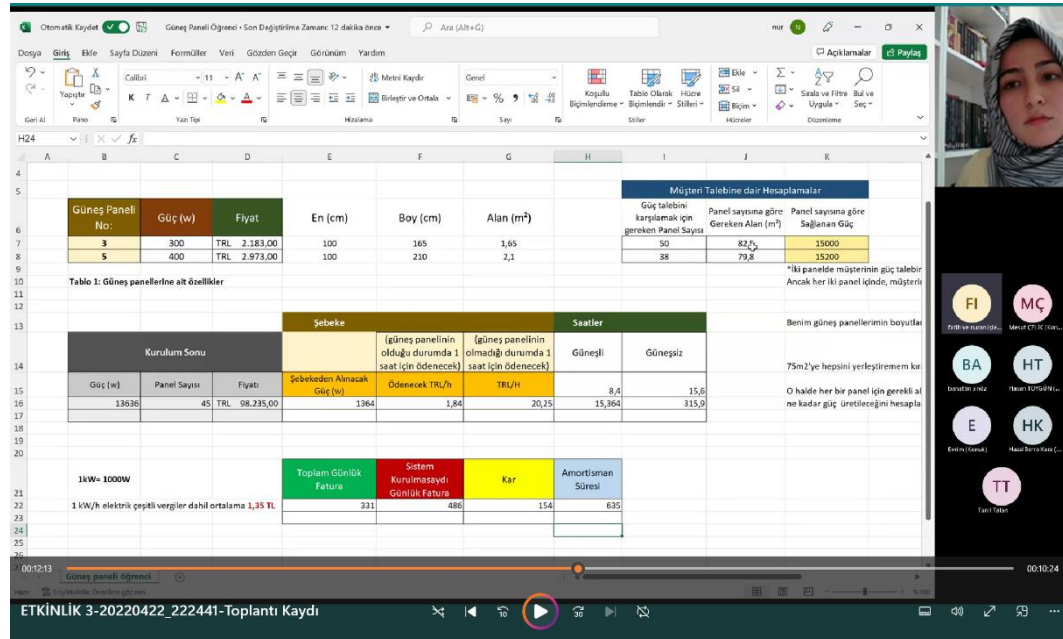


Figure 3.6 Group-1 results for third EDP implementation

As shown in Figure 3.6, Group 1(P1, P6, P8) presented their work and stated that they made separate calculations for two different solar panels. They reported that both panels meet the customer's power request, but the number of panels varies. In this case, they explained that they chose the panel type where they could use fewer panels because it produces more power and has a positive contribution to the installation cost. This group stated that they mostly aimed to shorten the payback period. In this direction, they decided to reduce the number of panels by one and offer solutions to the customer, where the rest is covered by the supply of grid electricity. They said that their main objective was to provide low, medium, and high options for the installation fee, but the payback period did not change significantly. They also emphasized that reducing the number of panels decreases

the customer's profit from the bill eventually. Offering multiple solutions and looking after the customer's profit reflects the engineers' ethical approach.

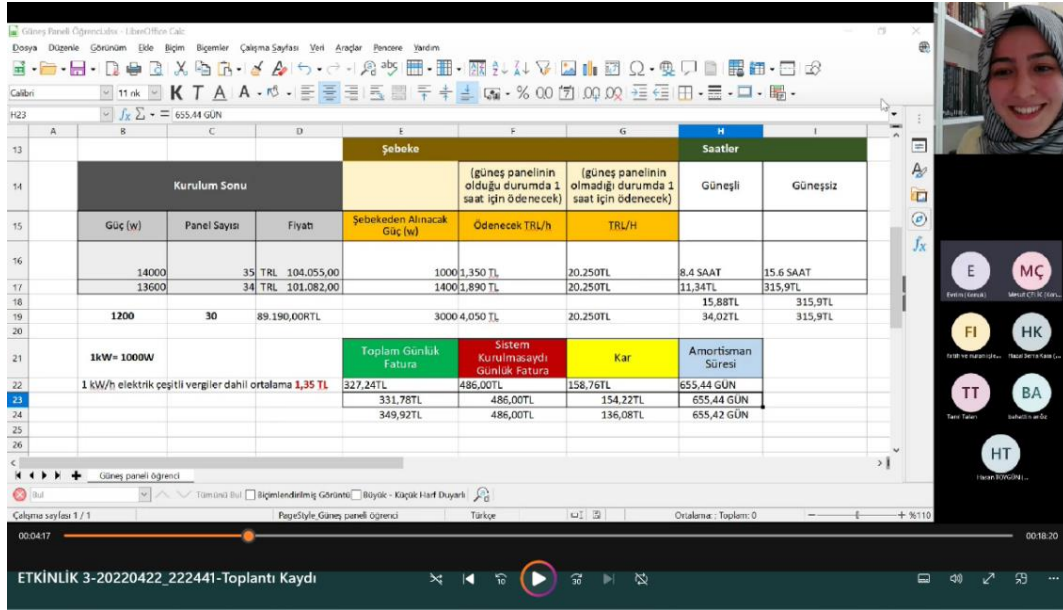


Figure 3.7 Group-2 results for third EDP implementation

In the 2nd group (P4, P5, P3, P7) study, as shown in Figure 3.7, unlike the other group, they wondered and calculated how much they exceeded the 75 square meter area when they increased the number of solar panels by one more. Thinking that they exceeded by about half an inch and that this could be tolerated on the roof, they presented a second proposal to the customer's request. The other groups stated that the legal regulations should be investigated, and, in this case, which stage should be returned to in EDP was discussed. They explained that when the number of panels increases, the cost of installation increases, but there is less needed to take energy from the electricity supply grid, which is more environmentally friendly, and that the payback period is reduced. Thus, more profit can be made in the long term. This solution added a distinct perspective to the study and was a useful example of the teachers putting their learning about EDP into practice.

3.2.2 In-Class Implementation

Teachers' professional growth was also evaluated through in-class practice. For this reason, "for in-class" was added to the category "Levels of Quality K-12 Engineering Edu." which was previously associated with the Personal Domain of

Practice. As it is known, what was justified from the data set for 12 indicators was determined. In this context, the observation notes and the interview statements of the teachers reflecting the POD, POD-PB, POD-PI, POD-TE, SEM, Team, and Comm-Engr indicators are presented below. In the classroom practice, 7 out of 12 indicators were justified, and "sometimes" was found appropriate according to the coding.

The teachers (P9 and P10) wanted to customize the EDP activity (the solar panel) and implement it in their classrooms. For this purpose, they selected a class of 12 students and allocated two weeks of time to make changes to their lesson plans. In addition, the school administration's support for the classroom application and allowing the use of the necessary materials for it provided great convenience.

Before starting the study, they informed the students, asked them to form their groups, and prepared a rubric for peer review of the study. The rubric consisted of several sections: effective presentation, accurate mathematical calculations, conformity with the constraints of the research and the client's criteria, and cost-effectiveness.



Figure 3.8 Teachers guidance during in-class implementation

In practice, the scenario was shared, and students were asked to identify the problem situation and brainstorm according to the criteria and constraints as seen in the Figure 3.8.

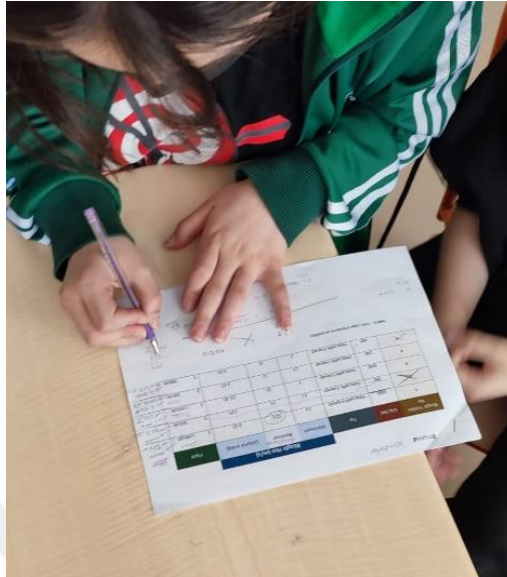


Figure 3.9 Students' EDP task outcomes during in-class implementation

The following week, the students discussed their solutions for the application and presented their work to the other groups by making the necessary calculations and researching the data they needed or consulting with the teacher in Figure 3.9.



Figure 3.10 Students' EDP task presentations

As a group, students gave themselves a company name. They gave points to other companies according to the rubric shared by their teachers. After each company presentation, various questions related to problem situation were asked through in-class discussion (Figure 3.10). With these questions, the students took the criticisms of their friends and talked about what they could change and what stage they should return to in the engineering design process.

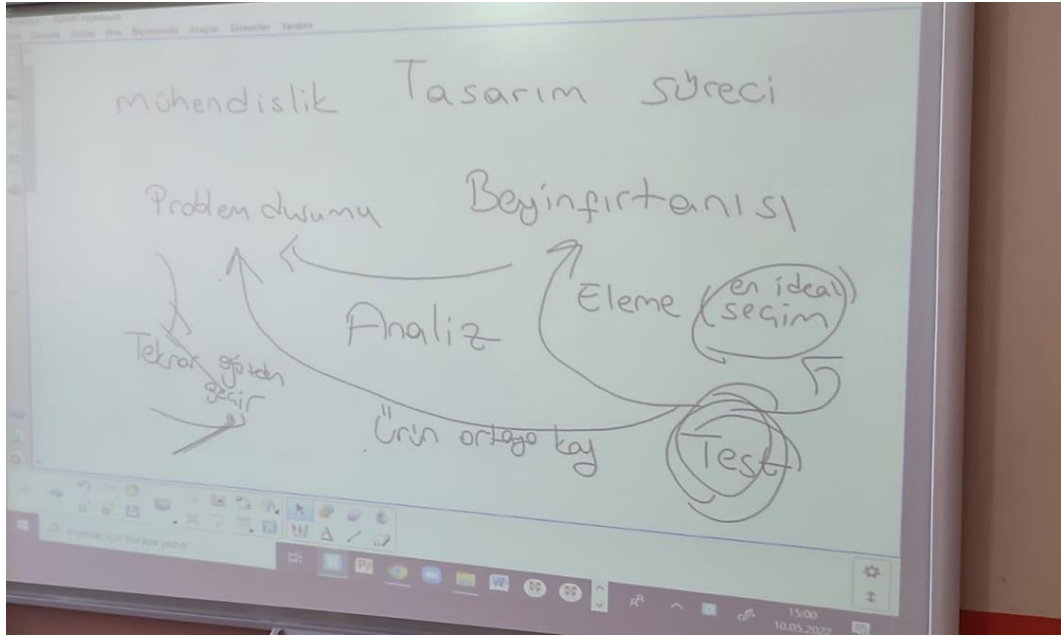


Figure 3.11 In-class implementation, brainstorme for EDP diagram

After all the presentations, the winning company was announced as the group with the most points. Although it was planned for two weeks, an EDP diagram reflecting the common opinion was created for EDP with the students in the next class period, as shown in Figure 3.11.

- **Apply Science, Engineering, and Mathematics (SEM)**

To address and solve problems that arise throughout the Engineering Design Process, this indicator requires the integration and application of disciplinary knowledge from science, engineering, and mathematics. As an example, P9 has a statement below for the integration of mathematical knowledge into EDP activities.

"First of all, there was real data. The students got some idea of the cost in that regard. Then, they also learned how to calculate them. Yes, they know about ratio and proportion,

but they really thought about which way an engineer should look at it by using this knowledge, or for those who went further, they thought things like "a, we need to calculate this here, that there".

- **Teamwork (Team)**

The teachers, who believed that students could form their own groups and wanted to give them the freedom to choose, asked students to determine the group members for the activity they were going to do. Regarding the grouping process, P9 and P10 made the following explanations about the difficulty they experienced in the grouping process, which they saw as a methodological error. In below, P9 stated that.

"I think the point we have difficulty with is grouping. Maybe it caused discrimination. For example, a student said, "I don't want Ahmet in my group; Ahmet can't do it." or he complained in his group, "Because Ahmet can't do it, Mehmet won." Or "I don't want the girls in my group" and things like that, which were not good. So, I think our method was wrong because we caused discrimination, and self-confidence became a problem. I think something can be set up like they are given freedom; it's like a lottery. In fact, it can be a process that we direct ourselves through because if we don't give the child freedom, they start to say, "I don't want to work with him/her."

Similarly, P10 shared her views about grouping like this.

"When we were separating the groups, we said that everyone should form a team of their own volition because we thought that since there would be group work, everyone should do it with someone with whom they can get along well or with whom they can do good teamwork. We didn't have much time, so when we arrived, everyone had already formed their own team. We wanted to give them a space of freedom, but as a result of this, things they could not get along with. Maybe it would have been better if we planned the groups ourselves. It would have been easier to manage the process."

Although P9 and P10 mentioned the negative effects of the method they followed in the grouping process, it was observed that the students engaged in division of labor during the process tried to find the best solution by respecting each other's ideas, established a sense of belonging when naming their companies, and tried to act jointly even when determining the company name. P9 supports this in her statement during the semi-structured interview.

"One student didn't know the calculation in his presentation very well, but he knew that it was an important part of the presentation because he was good at it, and the group asked him to do it. Students assigned the task to whichever one of them was better at what they

were good at; in other words, they progressed in the process with the idea that in group work, you can do this, you can do that, you say I am good at this, you can do that."

As can be seen from all these, the Teamwork indicator was provided in the activity.

3.2.2.1 Communication related to Engineering (Comm-Engr)

An important aspect of the peer assessment rubric that P9 and P10 gave to their students in the EDP activity is related to effective presentation. While explaining to the students that they could make their presentations as a group or by choosing a spokesperson from among them before making a presentation, it was observed that they emphasized that their solutions would be evaluated by the competitors (classmates) who entered the tender as per the scenario and therefore they should be clear, and there should be no mistakes in technical explanations or mathematical calculations. This shows that the "Communication-related to Engineering" indicator is met.

Overall, the level of quality engineering education demonstrated by the teachers during EDP implementation was compared with the in-class implementation. As a result of P9 having the code "sometimes" reflecting 6 indicators out of 12 and P10 having the code "often" reflecting 8 indicators, the fact that they justified 7 indicators over the classroom activity they planned and implemented together shows that it is the average of the two participants. Thus, the in-class implementation could be seen as a professional growth product of these two teachers.

3.3 What are the teachers' experiences with content or skills as an external source of knowledge and preferences for the learning environment as a source of external stimuli during EDP and classroom practice (external domain)?

The EDP implementation and the in-class implementation were designed to address the research question, as in the previous domain, by analyzing the findings related to the External Domain. Teachers' disciplinary experiences after the EDP implementation were examined in terms of content and skills and categorized. In addition, which learning environment the teachers would prefer if they were to implement in the classroom was also examined in this section since it is an external

factor. In the context of in-class implementation, students' experiences were similarly analyzed in terms of content and skills, and the rationale for teachers' choice of learning environment for in-class implementation was explained.

3.3.1 EDP Implementation

3.3.1.1 Teachers' Disciplinary Experience Related to Activities

Since the category Teachers' experiences (context or skills) specific to the activities was considered as an external source of information, the data set under this category was about teachers' experiences during the activities. Therefore, teachers' meaningful experiences and evaluations of the activities in terms of both context and skills were coded as "relevant." Statements that were outside of the activities or the implementation process or that were not sufficiently linked to or did not directly express these, especially in terms of context or skills, were coded as "irrelevant." There were 7 participants whose explanations were coded as "relevant" (P1, P2, P3, P6, P9, P10) and only 3 participants whose explanations were "irrelevant" (P4, P5, P7, P8).

The following statement of P5 is coded as "irrelevant" to serve as an example. "I realized that children get out of the monotony, that is, they get out of that ordinary classical education; I mean, they don't really know what engineering is. Maybe it can even bring out the good engineers in them." The statement shows that the participant shared his opinion that students can learn what engineering is by staying in the context of students' learning rather than talking about what he gained in the activities by talking about the content or different skills. On the other hand, P6's response to the same question asked to P5 was about his own experiences through the activities and therefore coded as "relevant."

" I didn't know the application with stop motion; it was interesting to me, and I even questioned myself why I didn't know it. There were too many details and too many steps; there were too many factors to think about. Then, we understood it as a group when we thought about it. We also had a hard time at times when we had to use our imagination, and it supported my creativity. While solving the problems, there were cases of failure, and we tried to solve them. In this process, we also thought about how we could solve these problems without harming the environment by considering the profit and needs of the customer. We thought in a multifaceted way, using all the elements and all the statistics. To speak for myself, I became more sensitive to the environment. "

Another "relevant" statement, which mentions her experiences of the activities in terms of both skills and context, belongs to P1 and constitutes straightforward evidence for the coding.

"On the subject of the environment, I was surprised to learn that plastics have a number and not all of them can be recycled. I thought we could just put them all in the recycling bin. I learned from my groupmates that there can be different perspectives. I think it is especially important to have professors from different disciplines at this point."

Although P2 could not participate in activity 3, her comprehensive explanation of the other two activities serves to show why the acquisitions in the PG process are coded as "relevant" in the context of activities.

"In the first session, there was a study on the change in the power of the wind, with the wind rose to be symmetrical and asymmetrical. From here, we talked about wind turbines and their designs. We had prepared a tender for wind turbines. In certain regions of Turkey, we created tenders and sales forms by making transactions related to the number of turbines according to the needs in the regions where the wind is high, or the wind speed is low. In the second session, you gave information about plastic waste according to the recyclability of plastic waste according to their levels. In this framework, we wrote a stop-motion story based on the materials we use in our home. A budget was determined, and a venue was determined. Also, I think this stop-motion application was very different. It is not very familiar, but it can attract the students' attention much more, the same as me. I couldn't attend the 3rd session, and I heard that you did a study on the sun and solar energy."

3.3.1.2 Teachers' Preference for Possible Learning Environments In-class

While private school teachers (P9, P10) preferred to participate in the study face-to-face, public school teachers preferred to participate online (P1, P2, P3, P4, P5, P6, P7, P8). Especially public-school teachers stated that online participation before PG provided them convenience in terms of time, energy, and money and that face-to-face applications could also be interactive, but they could reach the interaction they needed in this way. On the other hand, P9 and P10, who are private school teachers, stated that they wanted to participate face-to-face before PG because their schools provided a workshop classroom as a physical space, gave time for their teachers to participate, and provided material support.

After PG, teachers were informed about their preferences for learning environments, which were considered external sources of stimulus. When asked which environment they thought would be useful for their own students if they were

to apply these activities in the classroom, it was observed that only 2 participants (P3 and P9) preferred the same learning environment for their students as they did for themselves.

While 3 participants (P1, P2, P5, and P7) preferred online participation for their learning process, they preferred both learning environments for their students because they thought that both learning environments could be beneficial for their students in different ways. In this context, as an example, P2 stated that "It can be online or face to face, both of course have their own benefits. However, according to the conditions, it was advantageous to use the online platform. If it were face-to-face, it would still be enjoyable and instructive." P10 was among those who stated that students could benefit from both learning environments even if they participated in PG face-to-face. P3, on the other hand, stated that he could participate in PG online and preferred this for his students. His well-reasoned explanation in this regard is noteworthy.

"If the training we receive will be online, technological problems are an encumbrance. I can say that these are technical problems in distance education. Apart from that, there was no problem with this training. We also did group work together. We were also influenced and supported by each other. If we had done group work face to face, for example, there would have been no technical problems. In that situation, we would not have been able to benefit from Excel's conveniences. It could have been even more efficient, while in the face-to-face setting, we would have worked more synchronously with P1 and P8. The only difference between online and our daily lives is technical problems; if they are solved, I don't think there will be any other problems. It already provides the rest of the conveniences."

The other teachers (P4, P6, P8) recommended only a face-to-face learning environment for their students, except P9 (differently she participated in face-to-face PG), all of them preferred online in their learning process. For example, P6 explained in the following sentences, in this regard, that even if she participates in PG online, she prefers face-to-face for her students' learning environment. "Face-to-face, I think, would have been more productive. As a group, if three of us put our heads together and worked at a table, I think it would be more effective, and maybe more results would come out."

3.3.2 In-Class Implementation

3.3.2.1 Students' Experiences (Context or Skills) Specific to The Activities

Teachers explain their students' meaningful experiences and evaluations of the activity in terms of both context and skills. Thus, based on both participants' explanations related to the activity coded as "relevant." As an example, P10 made the following statement in the interview.

"Students gained market knowledge and learned to look more realistically. If real-life knowledge was added. For example, they were able to see that a wind turbine can be installed in Çanakkale and that the cost of a solar panel is this much, without making up their minds. Solving problems by using formulas is a fictitious thing, but in these activities, we mentioned, it was a more concrete example by thinking about it with real data, and students were involved actively in the process."

In the completed activity, thanks to P10 explanations, it is seen that students develop problem-solving skills by using information related to a real-life situation. This is a "relevant" explanation in terms of experiences for skills and learning.

3.3.2.2 Students' learning environment

Teachers prefer a face-to-face learning environment for implementation in their classrooms. They mentioned the justifications to apply within the face-to-face setting, either the school administration's support for such activities or the availability of physical space and time allocation.

3.4 What is the level of teachers' qualified explanations as salient outcomes in terms of lesson plans and learner outcomes (domain of consequences)?

Interview questions have addressed EDP and in-class implementations in the data analysis and were presented in two different headings while finding an answer for the last research question associated with the Domain of Consequence. The category "likely teaching plan" was used to group teachers' answers on creating lesson plans for EDP if they have a chance to integrate them into their lessons. The category "expected learning outcome for students," which is related to instructional plans, is related to the possible learning outcomes for students that might arise. Upon completion of in-class implementation, the lesson plans actively applied by

teachers are classified under the "applied teaching plan" category. Based on this, evaluations regarding what students have acquired are compiled under the heading "evaluated learning outcomes for students."

3.4.1 EDP Implementation

3.4.1.1 Likely Teaching Plan

Regarding the Domain of Consequence, the category of "Likely Teaching Plan" was created for teachers' explanations about their lesson plans reflecting what they realized, practiced, and acquired skills and experiences related to EDP after the PG. Briefly, teachers' explanations about how they would change their EDP activities in the future and what kind of plans they had obtained through semi-structured interviews.

In this section, teachers' explanations of their lesson plans were coded as "expert" if they were detailed, addressed certain basic steps related to EDP, or included a different idea unique to them, and as "novice" if they were more superficial. In this context, P8's explanation was coded as "expert," and she included creative ideas in her lesson plan.

"let's say 15 or 16 children can be formed in 4 groups. The teacher goes from table to table, again directing them as you did with us. Some progress is made in one lesson; then, in the next lesson, they are asked to continue this process. For example, if we analyzed the problem situation and brainstormed, I would try to get weekly feedback in writing. Secondly, I would definitely contact the art teacher and ask for help, maybe have a meeting with the students and the art teacher. That way, it would be an interdisciplinary work. In the first and third activities, I would apply the same method as you did. For example, a team from each class can be selected. A two-hour period is given to these teams. Preliminary information is given, but they are not told what will happen. It is said that you only need to know these in mathematical knowledge. For example, the first application is shown as a demo application. In the 3rd application, let's give the children an hour or a time, like 30 minutes, and it can be done in a competitive environment in the conference hall, as you know. The fastest and most appropriate solution to the criteria can be rewarded."

Like P8, "expert" coding was given to 5 participants (P3, P5, P6, P8, P10). On the other hand, the reason for giving the code "novice" to the explanation made by Participant P9 for the lesson plan is better understood from her statement below.

"I would like to do it with certain students, not in every class, to achieve good results. Here, we show students where I can use what I know differently in daily life. There is actually a place where he can use the issue of proportion. There is teamwork together. I want to pay more attention to these issues."

In P9's statements, it is seen that she used fewer concepts about EDP and did not detail her lesson plan. Among the participants, those who had statements like these (P1, P2, P4, P7, P9) were again given the code "novice".

3.4.1.2 Expected Learning Outcomes for Students

In addition to the likely EDP lesson plans, teachers shared their views on student outcomes that may emerge as a result of the teaching process. For this category, which is related to the domain of consequence, the teachers' statements about student outcomes were coded as those related to "cognitive," "effective," and "social." When the data set was analyzed using open coding, words such as problem-solving, reasoning, analytical thinking, identifying problems, learning disciplinary subjects, and brainstorming, the student looked around, that is, in a meaningful way, not blankly. Investigate everything that is said without correctly perceiving it and, in that way, solve daily life problems. Even if he is wrong, he can make his own mistakes, which were included in cognitive output. For affective outputs, expressions such as attention to environmental issues, looking in a more solution-oriented way, awareness, interest, and excitement were listed. For social output, participants frequently used the words group work, communication, and work collaboratively for student outcomes. Three participants (P1, P2, P3) had all three codes (cognitive, affective, social). On the other hand, P4 and P5 were given any code because they did not have an explanation in this regard. P1, one of the teachers who said that it can support all their students' cognitive, affective, and social development, used the following statements. "I think the teacher should definitely be a guide just like you guide us in practice. Instead of directing us to the right answers, you encouraged us to think and question. As teachers, we should pay attention to this situation." Meanwhile, P8 emphasized cognitive and social output, while P6 emphasized cognitive and affective.

"Thinking mentally, that is, the student's ability to think in multiple ways, increases because there are many factors, many items to think about. Being able to think and act all at once and in detail is an important cognitive outcome. This will make them feel happy; they will act like engineers as they see that they can solve it because I felt that way in the

applications. That's why I think they will come to better places mentally. Their analytical thinking also increases; that is, they act by thinking cause and effect."

As an example, when we look at P6's statement below, she mentions the affective outcome when she talks about acting like an engineer. When talking about students acquiring multiple and analytical thinking skills, it is related to the cognitive outcome.

Among the other participants, P9 and P10 only mentioned cognitive output, while P7 only mentioned social output. As an example, P9 shared this statement: "The student looks around, that is, in a meaningful way, not blankly. Investigate everything that is said without correctly perceiving it and, in that way, solve daily life problems. Even if he is wrong, he/she can make their own mistakes." P7, who emphasized social outcomes in her comment, used the following expressions.

Some of our students are very smart and have particularly good social skills; everyone likes them, and they get along with everyone. Some of them miss life; something happens around them, and they don't catch it. Acting in groups, communication, etc., are important. I think such practices can provide multidimensional development and especially social skills.

3.4.2 In-Class Implementation

3.4.2.1 Applied Teaching Plan

Although the implementing teachers said that there were problems in forming groups and that students had difficulties with the mathematics topic of ratio and proportion, the lesson plans were coded as "expert." In a class implementation, the lesson plan covered the basic EDP stages because the concept network they created about EDP with the students shows this. At the same time, asking the students to evaluate other groups according to the rubric and determining the winner of the tender shows that the students actively participated in the process. Participant 10 also mentioned this issue in the interview. "I was surprised at how active K was; it is still in front of my eyes. For example, one of the students did the math. One did the calculation, and the other did the presentation; two skills came together." Also, P9 stated that;

"I think students all made calculations, got excited, and said they wanted to do something like this again. Especially competing as a company made them very excited with each other."

This applied lesson plan was coded as "expert" because it was detailed, addressed certain basic steps related to EDP, or included a unique idea (peer-reviewed by using rubrics).

3.4.2.2 Evaluated Learning Outcomes for Students

P9 noted that the competitive nature of the activities excited the children. She underlined the value of giving students the chance to develop their skills in various areas and suggested better guiding questions and examples to help students grasp calculations and presentations. P10 emphasized that many talents came together in the group activity. She recommended that future practices should continue to emphasize the environment and include many academic areas to show students' expertise. She also discussed the difficulties students had in understanding ratio and proportion operations and suggested additional emphasis and explanation of the concepts to help students understand. Overall, participants (P9 and P10) appreciated the students' effort and engagement in the activities and noted the challenges in mathematics topics such as understanding ratios and proportions. It is clear from this that both teachers referred to the effective outcome when talking about their students' interest and enthusiasm for the work. Although they said that students had difficulties with ratios and proportions, it was observed that students completed the study with correct mathematical calculations as a result of the teachers' explanations through different examples. This indicates a cognitive outcome.

4.1 Discussion and Implications

Through a STEM module with an environmental theme, the study seeks to ascertain teachers' professional growth with respect to the Engineering Design Process (EDP) with the STEM module. The study's theoretical underpinning, the Interconnected Model of Professional Growth (IMPG) developed by Clarke and Hollingsworth, is made up of multiple case studies. The purpose of the study questions is to shed light on teachers' professional growth in relation to the IMPG domains, which include the personal, practice, external, and consequence domains. Based on their professional growth in the context of EDP implementation and in-class implementation, the study found four distinct types of teachers: "sophisticated," "eager," "average," and "naive."

The study's conclusions offer insightful information about the professional growth of teachers in the context of EDP with environment-themed STEM modules. The study's application of the IMPG model provides a multidimensional and integrative analysis, enabling a thorough comprehension of teachers' improvement across several areas. This strategy is in line with (Desimone, 2009) suggestions, which call for utilizing current research findings to enhance conceptualization, metrics, and technique when examining the effects of teachers' professional growth on both instructors and students. Using a theoretical framework like the IMPG model, the research guarantees a thorough and reliable examination of the professional growth of teachers.

By classifying instructors into distinct profiles based on their professional growth, such as "sophisticated," "enthusiastic," "average," and "naïve," the study offers a deep insight into the diverse experiences and development routes of teachers taking part in the EDP intervention. This method aligns with the viewpoint of Opfer & Pedder (2011), who examine the literature on teachers' professional growth methods using a complexity theory framework. The influence of learning

experiences on modifications in knowledge and classroom practices is highlighted by the writers, along with the generating systems of these practices.

The study's conclusions about how real-world experiences and classroom implementations affect the professional growth of teachers align with the body of research that highlights the value of real-world learning opportunities and useful applications for teacher preparation (Shume et al., 2022; Tipmontiane & Williams, 2021). The study's conclusions add to the body of knowledge by bringing to light the difficulties and complications that teachers encounter while integrating engineering methods into their lesson plans. This is consistent with earlier studies that have examined the challenges and worries that educators face when they pursue professional growth in engineering (Shahat et al., 2023). Also, the study's findings contribute to a better understanding of successful professional growth programs for educators by providing insightful information about how teachers can advance their careers in the context of implementing EDPs and providing instruction in-class.

Furthermore, Daugherty and Custer's (2010) study tackled the issues and worries brought up by educators during their professional growth in engineering, illuminating the complexities and roadblocks that educators might face when incorporating engineering practices into their teaching methodologies. Designing successful professional growth programs that meet teachers' needs and foster their development requires an understanding of these difficulties. Therefore, the PG intended for teachers who show "naive" or "average" results in terms of their professional growth can be revised, or the reasons for these results can be examined in future studies.

Additionally, the study's examination of the professional growth of teachers in relation to the implementation of EDP and in-class instruction offers insightful information about the influence of real-world experiences on instructors' progress. This is consistent with Winarno's (2020) findings, which indicate that implementing EDP can improve students' topic understanding and problem-solving abilities. A comprehensive picture of the growth of educators is offered by the study's focus on the Domain of Practice, External Domain, and Domain of Consequence, which highlights the significance of real-world experiences and classroom implementations in forming the professional growth of teachers.

The study's finding that instructors have varying degrees of professional growth corresponds with the body of research on models of professional growth for teachers. The body of research highlights the significance of professional growth that is specifically centered on comprehending and putting into practice particular processes, such as the Engineering Design Process, in educational settings (Shume et al., 2022; Topçu et al., 2022). Furthermore, the study's emphasis on the effects of in-class implementation on teacher professional growth aligns with the notion that longer-term programs for professional growth allow teachers to expand their knowledge and incorporate novel resources into their lesson plans (Mouza, 2006).

The body of research on professional growth for teachers, STEM education, and the integration of engineering needs to be considered in order to comprehend the significance of these findings fully. The influence of professional growth opportunities on teachers' pedagogical practices and subject understanding was highlighted in a study conducted by Christian et al. (2021) that focused on NGSS-based teachers' professional growth to adopt engineering techniques in STEM education.

The study conducted by Kekana & Gaigher's (2018) research looked at how participation in curriculum design and classroom implementation helped instructors improve professionally, offering insights into the significance of real-world experiences in supporting teachers' development. This is in line with this study's conclusions, which stressed the significance of in-class implementation in influencing teachers' growth with reference to EDP practices.

Further evidence of the importance of real-world connections in education comes from the study conducted by Ukobizaba et al. (2019), which found that most teachers use examples from daily life while instructing. Similarly, in this study, the problem situation presented to the teachers during the PG program was related to real life. Private school teachers (P9 and P10) also preferred to present the same real-life problem situation in their classroom practices. The teachers supported each other positively during classroom practices. This is in line with Ukobizaba et al. (2019), who emphasized the importance of real-life connections in education.

The idea that teachers who participate in engineering-focused programs are more likely to use the engineering design process (EDP) in their classrooms is highlighted

in Shume et al. (2022). In this study, on the other hand, it was concluded that private school teachers applied it in their classrooms while public school teachers did not. Although public school teachers do not use the engineering design process (EDP) in their classrooms, their statements indicate that they would like to apply it when they have sufficient opportunities. However, it was understood that they would not implement it due to reasons such as overcrowded classrooms, curriculum intensity, insufficient physical facilities, weak support from the school administration, and insufficient student readiness.

4.2 Recommendations

It is advised that professional growth programs for teachers include STEM module with environmental themes and the engineering design process considering the study's findings. This can support teachers' professional growth by enhancing their knowledge and expertise in these fields. The research also emphasizes how crucial it is to provide teachers chances to apply what they have learned in the classroom. Therefore, it is recommended that instructors be given additional support and tools to help them incorporate the engineering design process into their lesson plans. Future studies should also examine how these professional growth programs affect students' academic performance and interest in STEM disciplines.

In line with's investigation of educators' concerns throughout their professional growth, the research likewise emphasizes the difficulties and complications instructors have when integrating EDP into their teaching approaches (Daugherty & Custer, 2010).The success of programs for professional growth depends on recognizing and resolving these issues, underscoring the need to develop efforts to offer personalized guidance or look into the underlying reasons for these outcomes in order to make future changes.

Furthermore, it is advised to create material across a range of subjects to assess how STEM modules created across a range of themes affect teachers' professional growth. For instance, STEM courses with topics like energy, space, health, and entrepreneurship may enhance EDP experiences for instructors and provide a fresh viewpoint on how it's used in diverse educational settings.

Future studies might emphasize on how to leverage digital tools and incorporate technology into the STEM module curriculum. This need is demonstrated, in part, by the fact that

public school instructors were willing to engage in the online PGs in this study. Research on the usage of digital technologies by educators to enhance and support their EDP practices can shed light on how technology affects their professional growth procedures.

To assess the teachers' professional growth on EDP with STEM modules in a sustainable manner, long-term research is required. Research assessing the long-term effects of modules can show how these methods change over time and how they might be used to offer long-term professional growth.



5

CONCLUSION

5.1 Conclusion of EDP Implementation

When teachers' professional growth was evaluated according to IMPG domains, four different characteristics of teachers emerged. By analyzing the frequency of positive statements about teachers' professional growth from the matrix table, different characteristics such as "sophisticated," "eager," "average," and "naive" were defined.

Participants P1, P2, P3, P6, P9, and P10, who initially provided no or ill-informed explanations for EDP information in the Personal Domain category before professional growth, showed notable improvement in their explanations after PG. In the Domain of Practice, when analyzing the frequency of participants' responses to the 12 indicators, P1, P2, P3, P6, and P10 received mostly/usually positive coding. Evaluating the experience gained for the External Domain in terms of context and skills, participants P1, P2, P3, P6, P9, and P10 had "relevant" explanations for the activities. For the Domain of Consequence, the lesson plans were labeled as "expert" if they were detailed, covered fundamental EDP processes, or included unique ideas; participants with this coding were P3, P5, P6, P8, and P10. Regarding student outcomes, participants who mentioned at least two outcomes were P1, P2, P3, and P6.

5.2 Conclusion of In-class Implementation

Teachers P9 and P10 work in a private school. They designed and integrated the EDP activities with an in-class implementation. In the subcategory of IMPG domains, P10 was characterized as eager and P9 as average, and a significant portion of the codes expressed the professional growth of the teachers positively. Even if these teachers were coded as eager or average, their work on classroom practice was evaluated under the same domains (except personal domain). In this way, whether their professional growth is positively changed in the evaluation of the in-class implementation or not. This is because teachers' classroom practices are experiences and learning opportunities that reinforce their professional growth. The

similarity of relevant explanations for activities, serving as external sources of information and stimulus in the External Domain category, in both the learning and teaching processes suggests a positive impact on teachers' professional growth. Indeed, their explanations about the experiences they gained from the activities confirm such a conclusion.

Throughout the classroom implementations, P9 and P10 took on mentor roles as they modified their EDP-integrated lesson plans in response to the needs and profiles of their students. Classroom discussions and comprehensive EDP experiences played a pivotal role in fostering the teachers' professional growth. This was understandable by the EDP diagram, where students collaboratively expressed shared perspectives and actively assumed engineering roles. Notably, P9 was categorized as a "novice" in the "Likely Teaching Plan" after EDP, while P10 achieved an "expert" rating, indicating positive development in peer learning during in-class implementation, particularly in creating lesson plans. Both instructors eventually highlighted emotional and cognitive benefits in post-EDP interviews, despite having initially focused on cognitive outcomes. This suggests that classroom practice increases teachers' experiences with professional growth and highlights the significance of practical experience.

REFERENCES

- Akarsu, M., Okur Akçay, N. & Elmas, R. (2020). STEM Eğitimi Yaklaşımının Özellikleri ve Değerlendirilmesi Boğaziçi Üniversitesi Eğitim Dergisi, STEM Eğitimi, 155-175 Retrieved from <https://dergipark.org.tr/tr/pub/buje/issue/58376/842413>
- Akaygun, S. & Aslan Tutak, F. (2016). STEM images revealing stem conceptions of preservice chemistry and mathematics teachers. International Journal of Education in Mathematics, Science and Technology, 4(1), 56 - 71.
- Akgündüz, D., Aydeniz, M., Çakmakçı, G., Çavaş, B., Çorlu, M., Öner, T. & Özdemir, S. (2015). STEM eğitimi Türkiye raporu: “Günümüz modası mı yoksa gereksinim mi?”. İstanbul: İstanbul Aydın Üniversitesi STEM Merkezi.
- Akleman, E., Barroso, L., Capraro, M. M., Creasy, T., Fleming, K., He, W., Hong, L. and Williams, A. M. (2019). Recycling Plastics: Middle School Students Create Solutions During a Summer Camp. European Journal of STEM Education, 4(1), 10. <https://doi.org/10.20897/ejsteme/6341>
- Al-Matroushi, S. and Alkiyumi, M. (2022). Impact of transformative leadership practices of educational supervisors on the sustainable professional development of mathematics teachers. Journal of Educational and Social Research, 12(1), 261. <https://doi.org/10.36941/jesr-2022-0021>
- Areljung (2018). Why do teachers adopt or resist a pedagogical idea for teaching science in preschool?. International Journal of Early Years Education, 3(27), 238-253. <https://doi.org/10.1080/09669760.2018.1481733>
- Arık, M. & Topcu, M. S. (2020). Implementation of Engineering Design Process in the K-12 Science Classrooms: Trends and Issues. Research in Science Education. Springer.
- Avery, Z. K., & Reeve, E. M. (2013). Developing effective STEM professional development programs. Journal of Technology Education, 25(1), 55-69.
- Aydın, İ. (2018). Teacher career cycles and professional development., 15(4), 2047–2065. Retrieved from <https://www.j-humansciences.com/ojs/index.php/IJHS/article/view/5450>
- Bayazıt, N., Akaygün, S., Aslan-Tutak, F. & Demir, K. (2018) Bir STEM Öğretmen Eğitimi Örneği: Yenebilir Arabalar Etkinliğinin Öğretmen Eğitimi Açısından İncelenmesi. Fen Bilimleri Öğretimi Dergisi
- Beck, U. (1996) The Reinvention of Politics. Cambridge: Polity Press.
- Beck, U. (2000). What is Globalization? Cambridge: Polity Press.
- Benek, İ. and Akçay, B. (2022). The effects of socio-scientific stem activities on 21st century skills of middle school students. Participatory Educational Research, 9(2), 25-52. <https://doi.org/10.17275/per.22.27.9.2>
- Bell, D. (2016) The reality of STEM education, design, and technology teachers' perceptions: a phenomenographic study. Int J Technol Des Educ 26, 61–79

- Bonney, K. M. (2015). Case study teaching method improves student performance and perceptions of learning gains. *Journal of Microbiology & Biology Education*, 16(1), 21-28. <https://doi.org/10.1128/jmbe.v16i1.846>
- Brown, R., Brown, J., Reardon, K., & Merrill, C. (2011). Understanding STEM: Current perceptions. *Technology and Engineering Teacher*, 70(6), 5–9. doi:10.1136/bjsports-2011-090606.55
- Bybee, R. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, 7(1), 30-35
- Capobianco, B. M., DeLisi, J., & Radloff, J. (2018). Characterizing elementary teachers' enactment of high-leverage practices through engineering design-based science instruction. *Science Education*, 102(2), 342–376. <https://doi.org/10.1002/sce.21325>
- Capobianco, B. M., & Rupp, M. (2014). STEM teachers' planned and enacted attempts at implementing engineering design-based instruction. *School Science and Mathematics*, 114(6), 258-270.
- Cheung, Shek, Hui, Leung, Cheung (2022). Professional Development for Teachers of Gifted Education in Hong Kong: Instrument Validation and Training Effectiveness. *IJERPH*, 15(19), 9433. <https://doi.org/10.3390/ijerph19159433>
- Christian, Kelly, Bugallo (2021). NGSS-based teacher professional development to implement engineering practices in STEM instruction. *IJ STEM Ed*, 1(8). <https://doi.org/10.1186/s40594-021-00284-1>
- Checkoway, B. and Schön, D. A. (1985). The reflective practitioner: how professionals think in action. *Journal of Policy Analysis and Management*, 4(3), 476. <https://doi.org/10.2307/3324262>
- Chung C., Cartwright C. ve DeRose J. (2017) Robotics festival and competitions designed for STEM+C education. In M. Khine (Haz.), *Robotics in STEM education*. Springer, Cham.
- Clarke, D. J., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education*, 18(8), 947-967. doi:10.1016/S0742-051X(02)00053-7
- Corlu, M. S. (2012). A pathway to STEM education: Investigating pre-service mathematics and science teachers at Turkish universities in terms of their understanding of mathematics use in science. (PhD Thesis). Texas A & M University, USA.
- Craig, S. (2022). What Does an Emerging Intelligence Augmentation Economy Mean For Hf/e? Can Learning Engineering Help?. *Proceedings of the Human Factors and Ergonomics Society Annual*, 1(66), 460-464. <https://doi.org/10.1177/1071181322661283>
- Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Boston, MA: Pearson
- Cross, N.; Dorst, K.; Roozenburg, N. (eds) (1992) *Research in Design Thinking*. Delft, Netherlands, Delft University Press
- Cross, N. (2000). *Engineering design methods: Strategies for product design*. John Wiley & Sons.

- Cullis, J. (2019). Adam smith, natural extraction, and historical judgement: an unwarranted environmental legacy. *International Review of Environmental History*, 5(2), 115-121. <https://doi.org/10.22459/ireh.05.02.2019.05>
- Darling-Hammond, L., Hyler, M. E., Gardner, M. (2017). *Effective Teacher Professional Development*. Palo Alto, CA: Learning Policy Institute.
- Daugherty, J. and Custer, R. (2010). Secondary level engineering professional development: content, pedagogy, and challenges. *International Journal of Technology and Design Education*, 22(1), 51-64. <https://doi.org/10.1007/s10798-010-9136-2>
- Desimone, L. M. (2009). Improving impact studies of teachers' professional development: toward better conceptualizations and measures. *Educational Researcher*, 38(3), 181-199. <https://doi.org/10.3102/0013189x08331140>
- Diep, N., Thuy, H., Lai, D., Viet, V., & Chung, N. (2023). A comparison of three stem approaches to the teaching and learning of science topics: students' knowledge and scientific creativity. *International Journal of Education and Practice*, 11(2), 266-278. <https://doi.org/10.18488/61.v11i2.3336>
- Donmez, I. (2017). The views of students and team coaches about robotic competitions on the STEM education framework. *Journal of Research in Education, Science and Technology*, 2(1), 25-42.
- Dugger, E. W. (2010). Evolution of STEM in the United States. 6th Biennial International Conference on Technology Education Research, Australia.
- Duong, X. Q., Nguyen, N. H., Nguyen, M. T., & Thao-Do, T. P. (2022). Applying stem engineering design process through designing and making of electrostatic painting equipment in two rural schools in vietnam. *Jurnal Pendidikan IPA Indonesia*, 11(1), 1-10. <https://doi.org/10.15294/jpii.v11i1.31004>
- Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education*, 94(1), 103-120.
- English, L.D. (2016). STEM education K-12: perspectives on integration. *IJ STEM Ed* 3, 3 <https://doi.org/10.1186/s40594-016-0036-1>
- Esa, N. (2010). Environmental knowledge, attitude, and practices of student teachers. *International Research in Geographical and Environmental Education*, 19(1), 39-50. <https://doi.org/10.1080/10382040903545534>
- Farias, A. M., & Araujo, A. M. (2023). Life Experiences and Teaching Practices: An Analysis of Role Models in Accountancy. *Creative Education*, 14(3), 38-49. doi:10.4236/ce.2023.143038
- Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research In education* (8th ed.). New York: Mc Graw Hill.
- Fullan, M., & Stiegelbauer, S. (1991). *The new meaning of educational change*. Teachers College Press.
- Galanti, T. M. and Holincheck, N. (2022). Beyond content and curriculum in elementary classrooms: conceptualizing the cultivation of integrated stem teacher identity. *International Journal of STEM Education*, 9(1). <https://doi.org/10.1186/s40594-022-00358-8>

- Gandolfi (2020). "I Didn't Know How That Could Come to This Curriculum": Teacher's Growth Through the Development of Materials About Nature of Science. *Journal of Science Teacher Education*, 6(31), 610-630. <https://doi.org/10.1080/1046560x.2020.1730049>
- Guzey, S.S., Moore, T., Harwell, M. (2014). Development of an instrument to measure students' attitudes toward STEM. *Sch Sci Math* 114(6):271–279
- Guzey, S. S., Harwell, M., Moreno, M., Peralta, Y., & Moore, T. J. (2017). The Impact of Design-Based STEM Integration Curricula on Student Achievement in Engineering, Science, and Mathematics. *Journal of Science Education and Technology*, 26(2), 207-222.
- Gorbunova, N., Gluzman, N., & Osadchaya, I. (2021). Pedagogical reflection as a professional competence in conditions of lifelong pedagogical education. *SHS Web of Conferences*, 113, 00094. <https://doi.org/10.1051/shsconf/202111300094>
- Hancock, E. S., & Gallard, A. J. (2004). Preservice science teachers' beliefs about teaching and learning: The influence of K-12 field experiences. *Journal of Science Teacher Education*, 15(4), 281-291
- Hanno (2021). Immediate Changes, Trade-Offs, and Fade-Out in High-Quality Teacher Practices During Coaching. *Educational Researcher*, 3(51), 173-185. <https://doi.org/10.3102/0013189x211062896>
- Hehn, J., Meinel, C., & Leifer, L. (2020). Design thinking: A human-centered approach to innovation. In *The Design Thinking Playbook* (pp. 1-16). John Wiley & Sons.
- Honcharuk, V., Honcharuk, V., Zadorozhna, O., Sulym, V., Patiyevych, O. V., & Chystiakova, L. (2020). Developing environmental culture in future teachers during professional training. *Revista Romaneasca Pentru Educatie Multidimensionala*, 12(1), 244-264. <https://doi.org/10.18662/rrem/212>
- Howland, J. L., Jonassen, D., & Marra, R. M. (2012). Chapter 1: Goal of Technology Integration: Meaningful Learning. J. L. Howland, D. Jonassen, & R. M. Marra including, *Meaningful Learning with Technology* (p. 5-6). Boston: Pearson Education.
- Huang, X., Huang, R. (2022). Characterizing Teachers' Collective Learning Through Lesson Study As Document Development: a Case Study In China. *IJLLS*, 1(12), 92-105. <https://doi.org/10.1108/ijlls-03-2022-0035>
- Hynes, M., Portsmore, M., Dare E., Milto, E., Rogers, C., Hammer, D., & Carberry, A. (2011). Infusing engineering design into high school STEM courses.
- Isungset, M. A., Freese, J., Andreassen, O. A., & Lyngstad, T. H. (2021). Birth order differences in education originate in post-natal environments. <https://doi.org/10.1101/2021.06.01.446519>
- Jackson, P. W. (1974). *Life in classrooms*. Holt, Rinehart, and Winston.
- Johnson, K. and Stake, R. (1996). The art of case study research. *Modern Language Journal*, 80(4), 556. <https://doi.org/10.2307/329758>
- Jayarajah, K., Saat, R.M., & Rauf, R.A. (2014). A Review of Science, Technology, Engineering & Mathematics (STEM) Education Research from 1999-2013: A

- Malaysian Perspective. *Eurasia journal of mathematics, science, and technology education*, 10, 155-163.
- Jeong, S., & Kim, H. (2014). The effect of a climate change monitoring program on students' knowledge and perceptions of STEAM education in Korea. *Eurasia Journal of Mathematics, Science & Technology Education*, 11(6), 1321-1338.
- Johnson, D. W. (1993). *Reaching out: Interpersonal effectiveness and self-actualization*. Allyn & Bacon.
- Johnson, K. E. and Stake, R. E. (1996). The art of case study research. *The Modern Language Journal*, 80(4), 556. <https://doi.org/10.2307/329758>
- Johnson, S., Kraft, M., Papay, J. (2012). How Context Matters in High-need Schools: the Effects Of Teachers' Working Conditions On Their Professional Satisfaction And Their Students' Achievement. *Teachers College Record*, 10(114), 1-39. <https://doi.org/10.1177/016146811211401004>
- Kekana, M. C. and Gaigher, E. (2018). Understanding science teachers' classroom practice after completing a professional-development programme: a case study. *EURASIA Journal of Mathematics, Science and Technology Education*, 14(8). <https://doi.org/10.29333/ejmste/91831>
- Kelley, T. R., & Knowles, J. G. (2016). A Conceptual Framework for Integrated STEM Education. *International Journal of STEM Education*, 3, 11. <https://doi.org/10.1186/s40594-016-0046-z>
- Kennedy, T. & Odell, M. (2014). Engaging students in STEM education. *Science Education International*, 25(3), 246–258.
- Kim, Y., & Park, N. (2012) The Effect of STEAM Education on Elementary School Students' Creativity Improvement. In: Kim T. et al. (eds) *Computer Applications for Security, Control and System Engineering*. Communications in Computer and Information Science, vol 339. Springer, Berlin, Heidelberg.
- Koculu, A., Topcu, M. (2022). Exploration Of Pre-service Science Teachers' Engineering Design Performance Development. *EJES*, 10(9). <https://doi.org/10.46827/ejes.v9i10.4486>
- Lesseig, K., Slavitt, D., Nelson, T. H., & Seidel, R. A. (2016). Supporting middle school teachers' implementation of STEM design challenges. *School Science and Mathematics*, 116(4), 177–188. <https://doi.org/10.1111/ssm.12172>.
- Lewis, S. (2015). Qualitative inquiry and research design: choosing among five approaches. *Health Promotion Practice*, 16(4), 473-475. <https://doi.org/10.1177/1524839915580941>
- Lidstone, J. and Stoltman, J. (2012). International research in geographical and environmental education. *International Research in Geographical and Environmental Education*, 21(2), 93-94. <https://doi.org/10.1080/10382046.2012.680728>
- Lin, W., Chang, Y., & Chen, P. (2023). Environmental aesthetics and professional development for university teachers in china. *Humanities and Social Sciences Communications*, 10(1). <https://doi.org/10.1057/s41599-023-01581-6>

- Linh, N. Q. and Hường, L. T. T. (2021). Engineering design process in stem education: an illustration with the topic “wind energy engineers.” *Journal of Physics: Conference Series*, 1835(1), 012051. <https://doi.org/10.1088/1742-6596/1835/1/012051>
- Long, N. T., Yen, N. T. H., & Hanh, N. V. (2020). The role of experiential learning and engineering design process in k-12 stem education. *International Journal of Education and Practice*, 8(4), 720-732. <https://doi.org/10.18488/journal.61.2020.84.720.732>
- Massachusetts Department of Education. (2006). Massachusetts science and technology/engineering curriculum framework. Retrieved from <https://www.doe.mass.edu/frameworks/scitech/2006-04.pdf>
- Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). *STEM: country comparisons*. Melbourne: Australian Council of Learned Academies.
- Margot, K.C., Kettler, T. (2019). Teachers’ perception of STEM integration and education: a systematic literature review. *IJ STEM Ed* 6, 2 <https://doi.org/10.1186/s40594-018-0151-2>
- Milner-Bolotin, M. (2018). Evidence-based research in stem teacher education: from theory to practice. *Frontiers in Education*, 3. <https://doi.org/10.3389/feduc.2018.00092>
- Moore, T. J., Glancy, A. W., Tank, K. M., Kersten, J. A., Smith, K. A., & Stohlmann, M. S. (2014). A Framework for Quality K-12 Engineering Education: Research and Development. *Journal of Pre-College Engineering Education Research (J-PEER)*, 4(1), Article 2. <https://doi.org/10.7771/2157-9288.1069>
- Mouza, C. (2006). Linking professional development to teacher learning and practice: a multi-case study analysis of urban teachers. *Journal of Educational Computing Research*, 34(4), 405-440. <https://doi.org/10.2190/2218-567j-65p8-7j72>
- National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.
- National Science Board. (2007). *Science and Engineering Indicators 2004*. from <http://www.nsf.gov/statistics/seind04/>
- National Science Board. (2012). *Science and Engineering Indicators 2012*. Arlington VA: National Science Foundation (NSB 12-01).
- National Research Council (2009) *Engineering in K-12 education: understanding the status and improving the prospects*. The National Academies Press, Washington, DC.
- National Research Council (2012) *A framework for K–12 science education*. Retrieved from www.nap.edu/catalog.php?record_id=13165.
- National Academy of Engineering (NAE) and National Research Council (NRC). (2014). *STEM integration in K-12 education: status, prospects, and an agenda for research*. In M. Honey, G. Pearson, & H. Schweingruber (Eds.), *Committee on K-12 engineering education*. Washington, DC: National Academies Press.

- NGSS Lead States (2013). Next Generation Science Standards: For States, by States. Washington DC: The National Academies Press.
- Opfer, V. D. and Pedder, D. (2011). Conceptualizing teacher professional learning. *Review of Educational Research*, 81(3), 376-407. <https://doi.org/10.3102/0034654311413609>
- Ostler, E., (2012). 21st century STEM education: a tactical model for long-range success. *International Journal of Applied Science and Technology*, 2(1), 28- 33.
- Okan Gökten, P. (2018). Karanlıkta Üretim: Yeniçağda Maliyetin Kapsamı. *Muhasebe Bilim Dünyası Dergisi*, 20 (4), 880-897. DOI: 10.31460/mbdd.460897
- Oxford University Press. (15.11.2023). *Oxford Learner's Dictionaries*. <https://www.oxfordlearnersdictionaries.com/>
- Ozkan, G., & Topsakal, U. (2017). Examining Students' Opinions about STEAM Activities. *Journal of Education and Training Studies*, 5(9), 115-123. doi:<http://dx.doi.org/10.11114/jets.v5i9.2584>
- Partnership for 21st Century Learning. (2017). P21 Framework Definitions. Erişim tarihi: 03.01.2021. Erişim adresi: <http://www.p21.org/our-work/p21-framework>.
- Ponte, J., Quaresma, M., Mata-Pereira, J. (2022). The Development Of Teachers' Knowledge In a Lesson Study. *IJLLS*, 1(12), 78-91. <https://doi.org/10.1108/ijlls-02-2022-0025>
- Piqueras, Achiam (2019). Science museum educators' professional growth: Dynamics of changes in research–practitioner collaboration. *Sci. Ed.*, 2(103), 389-417. <https://doi.org/10.1002/sce.21495>
- Razali, F., Sulaiman, T., & Ayub, A. F. M. (2022). Factors of learning towards creating blended learning curriculum using learning management system in higher education during Covid-19. *International Journal of Instruction*, 15(4), 723- 744. <https://doi.org/10.29333/iji.2022.15439a>
- Savin-Baden, M., & Major, C. H. (2013). *Qualitative Research*. Routledge.
- Scherer, H., McKim, A., DiBenedetto, C., & Robinson, K. (2019). Making sense of the buzz: a systematic review of "stem" in agriculture, food, and natural resources education literature. *Journal of Agricultural Education*, 60(2), 28-53. <https://doi.org/10.5032/jae.2019.02028>
- Schipper, Goei, Veen (2017). Professional growth in adaptive teaching competence as a result of Lesson Study. *Teaching and Teacher Education*, (68), 289-303. <https://doi.org/10.1016/j.tate.2017.09.015>
- Schwartz, H. S. and Schön, D. A. (1987). The reflective practitioner: how professionals think in action. *Administrative Science Quarterly*, 32(4), 614. <https://doi.org/10.2307/2392894>
- Shahat, M. A., Al-Balushi, S. M., & Amri, M. A. (2023). Measuring preservice science teachers' performance on engineering design process tasks: implications for fostering stem education. *Arab Gulf Journal of Scientific Research*. <https://doi.org/10.1108/agjsr-12-2022-0277>

- Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to stem education. *International Journal of STEM Education*, 4(1). <https://doi.org/10.1186/s40594-017-0068-1>
- Shume, T., Bowen, B., Altimus, J., & Kallmeyer, A. R. (2022). Rural secondary stem teachers' understanding of the engineering design process. *Theory & Practice in Rural Education*, 12(2), 89-103. <https://doi.org/10.3776/tpre.2022.v12n2p89-103>
- Sikhosana, L. (2022). Clarifying the significance of instructional methodologies for environmental education integration. *International Journal of Research in Business and Social Science* (2147-4478), 11(7), 240-248. <https://doi.org/10.20525/ijrbs.v11i7.2016>
- Smith, J. (2018). Best practices in STEM professional development. *Journal of STEM Education*, 10(2), 45-60.
- Soomro, S., Casakin, H., Georgiev, G. (2021). Sustainable Design and Prototyping Using Digital Fabrication Tools for Education. *Sustainability*, 3(13), 1196. <https://doi.org/10.3390/su13031196>
- Spector, J. M. (2012). *Foundations of educational technology: Integrative approaches and interdisciplinary perspectives*. Routledge.
- Shume, T., Bowen, B., Altimus, J., & Kallmeyer, A. R. (2022). Rural secondary stem teachers' understanding of the engineering design process. *Theory & Practice in Rural Education*, 12(2), 89-103. <https://doi.org/10.3776/tpre.2022.v12n2p89-103>
- Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for Teaching Integrated STEM Education. *Journal of Pre-College Engineering Education Research (J-PEER)*, 2(1), Article 4. <https://doi.org/10.5703/1288284314653>
- Tipmontiane, K. and Williams, P. J. (2021). The integration of the engineering design process in biology-related stem activity: a review of thai secondary education. *ASEAN Journal of Science and Engineering Education*, 2(1), 1-10. <https://doi.org/10.17509/ajsee.v2i1.35097>
- Timur, S., Timur, B., & Imer Cetin, N. (2019). Effects of STEM Based Activities on In-Service Teachers' Views. *Educational Policy Analysis and Strategic Research*, 14(4), 102-113.
- Tuluri, F. (2017). *STEM Education by Exploring Robotics*. M. S. Khine (Haz.), *Robotics in STEM education* (s. 195-209). Springer, Cham.
- Topçu, M. S. and Çiftçi, A. (2023). Co-design and implementation of community-based engineering enriched science units: exploration of pre-service science teachers' professional development. *Teaching and Teacher Education*, 127, 104095. <https://doi.org/10.1016/j.tate.2023.104095>
- Topçu, M. S., Atabey, N., & Çiftçi, A. (2022). Supporting Science Teachers' Professional Development and Teaching Practices: A Case Study of Socioscientific Issue-Based Instruction. In Y. S. Hsu, R. Tytler, & P. J. White (Eds.), *Innovative Approaches to Socioscientific Issues and Sustainability Education. Learning Sciences for Higher Education*. Singapore: Springer. https://doi.org/10.1007/978-981-19-1840-7_9.

- Van Haneghan, J. P., Pruet, S. A., Neal-Waltman, R., & Harlan, J. M. (2015). Teacher Beliefs about Motivating and Teaching Students to Carry out Engineering Design Challenges: Some Initial Data. *Journal of Pre-College Engineering Education Research (J-PEER)*, 5(2), Article 1.
<https://doi.org/10.7771/2157-9288.1097>
- Vasquez, J. A., Sneider, C. I. & Comer, M. W. (2013). STEM lesson essentials, grades 3-8: Integrating science, technology, engineering, and mathematics. NH: Heinemann.
- Voogt, J., Westbroek, H., Handelzalts, A., Walraven, A., McKenney, S., Pieters, J., & de Vries, B. (2015). Collaborative design as a form of professional development. *Instructional Science*, 43(2), 259-282. doi:10.1007/s11251-014-9340-7
- Vossen, T.E., Tigelaar, E.H., Henze, I. et al. (2020). Student and teacher perceptions of the functions of research in the context of a design-oriented STEM module. *Int J Technol Des Educ* 30, 657–686
<https://doi.org/10.1007/s10798-019-09523-7>
- Yıldırım, B. (2016). An analysis and meta-synthesis of research on STEM education. *Journal of Education and Practice*, 7(34), 23-33.
- Yildirim, B., & Selvi, M. (2016). Examination of the effects of STEM education integrated as a part of science, technology, society, and environment courses. *Journal of Human Sciences*, 13(3), 3684-3695.
- Zhao, W., Huang, R., Cao, Y., Ning, R., Zhang, X. (2022). A Teacher's Learning of Transforming Curriculum Reform Ideas Into Classroom Practices In Lesson Study In China. *IJLLS*, 2(11), 133-146. <https://doi.org/10.1108/ijlls-07-2021-0056>
- Zwart, Wubbels, Bergen, Bolhuis (2007). Experienced teacher learning within the context of reciprocal peer coaching. *Teachers and Teaching*, 2(13), 165-187.
<https://doi.org/10.1080/13540600601152520>
- Wendell, K. B., & Rogers, C. (2013). Engineering design-based science, sciencecontent performance, and science attitudes in elementary school. *Journal of Engineering Education*, 102(4), 513–540.
<https://doi.org/10.1002/jee.20026>
- Weld, J. (2017) Creating a STEM Culture for Teaching and Learning. National Science Teacher Association Press. USA
- Winarno, N. (2020). The steps of the engineering design process (edp) in science education: a systematic literature review. *Journal for the Education of Gifted Young Scientists*, 8(4), 1345-1360. <https://doi.org/10.17478/jegys.766201>
- Winarno, H., Sutopo, W., & Prasetyo, A. P. B. (2020). Design Thinking Approach in Engineering Design Education. *Journal of Physics: Conference Series*, 1477(1), 012032.
- Wang, H. H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research (J-PEER)* 1(2), 1-13.

A

ETHICS COMMITTEE APPROVAL



YILDIZ TEKNİK ÜNİVERSİTESİ
Sosyal ve Beşeri Bilimler Araştırmaları Etik Kurulu

Toplantı Tarihi: 22.12.2021

Toplantı No: 2021.12

SOSYAL VE BEŞERİ BİLİMLER ARAŞTIRMALARI ETİK KURULU TOPLANTI KARARI

Yürütücülüğünü Üniversitemiz Fen Bilimleri Enstitüsü öğretim üyelerinden Prof. Dr. Mustafa Sami TOPÇU danışmanlığında lisansüstü öğrencisi NUR CENGİZ tarafından yapılacak olan “Çevre Temalı STEM Etkinliklerinde Mühendislik Uygulamaları Öğretmen Mesleki Gelişimi Örneği” adlı çalışma ve bu çalışmada kullanılacak veri toplama araçları ve yöntemlerine ilişkin bilgilerde etiğe aykırı herhangi bir bulguya rastlanmamıştır.

Etik Kurul Üyeleri

Prof. Dr. Murat DONDUKAN
Başkan

Prof. Dr. Ali ERYILMAZ
Üye

Prof. Dr. Guinayat GÖLBAŞI ŞİMŞEK
Üye

Doç. Dr. Mehmet Emin KAHRAMAN
Üye

Doç. Dr. Senay OGUZTİMUR
Üye

Doç. Dr. Yasin ŞEHİTOĞLU
Üye

Dr. Öğr. Üyesi Güzin AKYILDIZ
Üye

B

MINISTRY OF NATIONAL EDUCATION RESEARCH PERMIT



T.C.
İSTANBUL VALİLİĞİ
İl Millî Eğitim Müdürlüğü

GÜNLÜDÜR

Sayı : E-59090411-44-44854762
Konu : Anket ve Araştırma İzni (Nur CENGİZ)

03.03.2022

YILDIZ TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
(Eğitim Öğretim Rektör Yardımcılığı)

İlgi : a) Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 21.02.2020 tarihli ve 2020/2 sayılı genelgesi.
b) Valilik Makamının 28.02.2022 tarihli ve 44609481 sayılı oluru.

Valilik Makamının Anket ve Araştırma İzni konulu ilgi (b) oluru ve kullanılması uygun görülen ölçme araçlarının Müdürlüğümüzce mühürlenmiş örnekleri ekte gönderilmiştir.

İlgi (a) genelgenin 28. maddesinde; "Araştırma uygulama izni alan kamu kurum ve kuruluşları, uluslararası kuruluşlar, üniversiteler, sivil toplum kuruluşları ve araştırmacılar tamamladıkları bilimsel araştırma ile ilgili sonuç raporlarını, izni aldıkları ilgili birime çalışma bitiminden itibaren 30 gün içerisinde göndereceklerdir." ifadesi yer almaktadır.

Olur gereğince işlem yapılması ve araştırma sonuç raporunun ekte sunulan örneğe göre Müdürlüğümüz Strateji Geliştirme Şubesine gönderilmesi hususlarında gereğini arz ederim.

Abdurrahman ENSARİ
İl Millî Eğitim Müdürü a.
Şube Müdürü

Ek:
1- Valilik Oluru (1 Sayfa)
2- Rapor Örneği
3- Ölçekler

C

STEM MODULE

STEM module activities are shared sequentially according to the order below.

1.1 Wind Power (Inquiry based activity)

1.2 Wind Tribune Farm (Installing wind tribune at the site selected for the customer)

2.1 Getting to Know the Plastics in Our Lives (Inquiry based activity)

2.2 Stickman Animation Company (Creating stop motion for the company)

3.1 Let's Heat Water Without Polluting Nature (Inquiry-based activity)

3.2 SES (Solar Energy Systems) (Installing solar panel on the roof of a building for the customer)

1

Rüzgâr Gücü

Genel Bakış:

Dünyadaki hava kirliliğini azaltmaya yardımcı ve yenilenebilir bir enerji kaynağı olan rüzgâr enerjisi oldukça verimli, çevreci alternatif bir enerji kaynağıdır. Evleri ısıtmak, sokakları ve binaları aydınlatmak için ihtiyacımız olan elektriği rüzgârın gücünden faydalanarak üretmek oldukça kolay. Bunun içinse çeşitli rüzgâr türbinleri tasarlanmıştır. Bu deneyimizde ise rüzgâr türbinlerinin basit bir modeli olan rüzgâr gülünden yararlanarak rüzgâr enerjisini elde etmek için simetrik veya asimetrik nasıl bir tasarımın verimli olacağını bulmaya çalışacağız. Etkinliğe başlamadan önce simetrik veya asimetrik tasarımların verimliliği ilgili tahminlerinizi Bilimsel Notlar bölümüne yazın/çizin.

Gerekli Malzemeler:

- ❑ 8 yapraklı rüzgâr gülü
- ❑ Ağır yastıklar veya kitap yığınları
- ❑ Mezura veya cetvel
- ❑ Küçük boyutlu renkli yapışkan kağıtlar
- ❑ Kalem
- ❑ Saç kurutma makinesi
- ❑ Makas





01

Rüzgâr gülünüzün birini hava cereyanı olmayan bir odada iki yastık veya iki kitap yığını arasına yerleştirin.



Eğer ki elinizde hazır 8 yapraklı bir rüzgâr gülü yoksa yanda yer alan kare kod veya bağlantı linkinden yararlanarak nasıl yapıldığını öğrenebilir ve atık kağıtlardan kendin de bir rüzgâr gülü oluşturabilirsin.

https://www.youtube.com/watch?v=7Qmz_u7a5m4

02

Mezura veya cetvel yardımı ile rüzgâr gülünün bulunduğu zeminden itibaren düz bir şekilde geriye doğru birkaç metre mesafe bırakın.

03

Yapışkan kağıtlarınızdan yedisini 0'dan 7'ye kadar numaralandırın. Bu numaralar rüzgâr gülünüzden çıkaracağınız kanat sayısını ifade etmektedir. Örneğin rüzgâr gülünüzden 3 kanat çıkardığınızda 3 numaralı yapışkan kağıdını kullanın.



04

Denediğiniz ilk rüzgâr gülü 8 yapraklı olmalıdır, yani henüz yaprakları kesilmemiş demektir.

05

Saç kurutma makinasını rüzgâr gülünüzle aynı seviyede tutun ve düşük güçte çalıştırın. Rüzgâr gülünüz dönmeyi durdurana kadar yavaşça geri gidin.

Önemli bir not her denemenizde saç kurutma makinasını aynı güç seviyesinde kullanın. Rüzgâr gülü ile fon makinası arasındaki başlangıç mesafesini ise yine her denemenizde aynı tutmaya özen gösterin.



06

Rüzgâr gülü durduğu anda fön makinasını tuttuğunuz yere yapışkan kağıtlardan ilki olan 0 yazılı kâğıdı yapıştırın. Mezura veya cetvel ile rüzgâr gülünün bulunduğu zeminden itibaren yapışkan notunuz arasındaki mesafeyi ölçün ve tabloya not alın.



Rüzgâr Güllü Deneyi Veri Tablosu		
Rüzgâr Güllünden Çıkarılan Kanat Sayısı	Rüzgâr Güllünün Şekli	Rüzgâr Güllünün Dönmeyi Durduğu Mesafe (cm)
0	Symmetric	
1	Asymmetric	
2	Symmetric	
3	Asymmetric	
4	Symmetric	
5	Asymmetric	
6	Symmetric	

07

Rüzgâr güllünüzden makas yardımı ile bir kanat çıkarın ve yastıklar veya kitap yığınları arasına yeniden yerleştirin. Yalnızca bir kanat kalana kadar 5. ve 6. adımları tekrarlayın.

08

Tablodan yararlanarak kaç adet kanat sayısının ve tasarımının verimli olduğunu bulmaya çalışın. Deneyle ilgili gözlemlerinizi/sonuçlarınızı Bilimsel Notlar bölümüne yazın/çizin.



İsim _____

Tarih _____

BİLİMSEL NOTLAR

Rüzgar gülünün simetrik veya asimetrik bir tasarımı olmasının ne gibi etkileri olabilir? Deney süresi boyunca rüzgar gülünden kanat çıkardığımızda ne gibi değişiklikler oldu? Düşüncelerini yaz ve gözlemlerin/tahminlerin hakkında bir çizim yap.

TAHMİNLERİM

Bir resim çiz ve rüzgar gülü ilgili tahminlerini anlat. Neler olmasını bekliyorsun?

GÖZLEMLERİM

Bir resim çiz ve gözlemlerini paylaş. Neler oldu?

Rüzgar Türbinü Çiftliği

"PROBLEM DURUMU"



Bildiğimiz üzere Yenilenebilir enerji kaynaklarından biri rüzgar türbinleridir. Daha önce hiç bir rüzgar türbinü gördün mü? Bir önceki aktivite de rüzgar türbinlerinin basit bir modeli olan rüzgar gülünden yararlanarak rüzgar enerjisini elde etmek için nasıl bir tasarımın verimli olacağını bulmaya çalıştık. Bugünkü görevin ise geleceğin mühendisleri olarak rüzgar tribünü çiftliği kurmak isteyen 3 farklı müşteriden biri için ihale teklifi hazırlamaktır. Her bir grup öncelikle kendisine bir firma ismi belirlemeli ve firmasına başvuran müşterisinin talebine dair detayları gözden geçirmelidir. Aynı müşteri için iki grup iki farklı firma olarak ihale teklifi sunacak olup en iyi teklif ihalenin kazananı olacaktır. Dolayısıyla müşterinin talebini ve rüzgar türbini çiftliğinin kurulacağı lokasyona dair detayların incelenmesi ve bir bütçe çıkartılması gerekmektedir. Haydi başlayalım!



ARAŞTIRMAYA BAŞLA VE VİDEOLARA GÖZ AT:

Rüzgar türbinleri nasıl çalışır? Nasıl yapılır veya nelere dikkat etmek gerekir? Bunun için küçük bir başlangıç olması adına aşağıda yer alan kare kodları kullanarak video linklerine ve makalelere erişim sağlayabilirsin.

LEARN ABOUT WIND FARMS



BUILD A WIND
TURBINE



TURKIYE RÜZGAR
ATLASI



Rüzgar Türbinü Çiftliği

"PROJE DOSYASI"

SORUNU TANIMLA VE ANALİZ ET



OLASI ÇÖZÜMLER BUL VE EN İYİSİNİ SEÇ

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____



MATERYALLER

Rüzgar Türbinü Çiftliği

"PROJE DOSYASI"

BİR ORNEK YAP VE BUNU TEST ET



PLANLANAN VE TAMAMLANAN
PROSEDÜRLER

TASLAK ÇİZİM

(Rüzgar türbinü tasarımı
için ekte yer alan taslak çizim
bölümünü kullanabilirsin)



Rüzgar Türbinü Çiftliği

"ÜRÜNÜ PAYLAŞ"

Bu bölüm de bulduğun çözümleri ve geliştirdiğin rüzgar türbinü çiftliğini ve tamamladığın anemometre hakkındaki detayları paylaşmalısın. Bunun için proje dosyasını ve ürün görsellerini öncesinden öğretmene veya arkadaşlarına paylaşarak ürününü değerlendirebilir ve böylece daha iyisini düşünebilirsin.

Ayrıca proje video sunumunu ve görsellerini **ncengiz@turkiyemaarif.org** adresine göndererek değerlendirmeye katılabilir ve çalışmanın sosyal medya platformlarında paylaşılmasını sağlayabilirsin.



2

Hayatımızdaki Plastikleri Tanıyalım

Genel Bakış:

Bildiğimiz üzere plastikler petrol ve türevlerinden elde edilir. Bununla birlikte, bütün plastikler aynı değildir ve bu, hepsinin aynı şekilde bertaraf edilip geri dönüştürülemeyeceği anlamına gelir. Sadece ev ortamında kullanmış olduğumuz plastikler nelerdir? Belki de çok daha önemli bir soru kullandığımız her plastik geri dönüştürülebilir mi? Gelin birlikte hayatımızdaki plastikleri biraz daha yakından tanıyalım.

Gerekli Malzemeler:

- ❑ Çeşitli atık plastik maddeler
- ❑ Su
- ❑ Büyük bir kap
- ❑ Makas
- ❑ El feneri



İlginç bir Bilgi:

Nepal'in başkenti Katmandu'da da atık büyük bir sorun.

"Özel şirketler, evlerden atık topluyor, ancak herkes hizmetin karşılığını ödeyemiyor." Atıklarını şehir içinde belirli bölgelere götürme veya sokaklarda bırakma seçeneğine sahip olamayanlar. "

"Gayri resmi sokak toplama ve atık alanları, çocuklar da dahil olmak üzere 15.000 kişiye atıklardan geçimini sağlamak için fırsatlar sağlıyor.





01

Evde kullanmış olduğunuz, çeşitli kullanım alanlarından, plastik özelliği bakımından farklı türde plastikleri biraya toplayın.

02

İlginç bir bilgi bölümünde paylaşılmış olunan örneğin Nepal'deki plastik hurdacılarına toplamış olduğunuz plastikleri satacağınızı düşünelim.

Toplamış olduğunuz plastikleri bir plastik hurda satıcısına satmak istediğimizde en fazla geliri sağlayacak olan plastikleri belirli kategoriler altında farklı şekilde sınıflandırın. (Örneğin; yüksek, orta, düşük fiyatlı plastikler şunlardır gibi.) Kategorilendirme için aşağıdaki gibi bir tablodan yararlanabilirsiniz.

Plastik Kategorileri		
A.	B.	C.

03

Hangi plastiği hangi kategori de sınıflandırdığınızı nedenleri ile birlikte paylaşın.

Plastikler ile ilgili tahminlerinizi Bilimsel Notlar sayfasına yazın/çizin.



04

Test için dört plastik nesneden numuneler (yaklaşık 5 cm²) kesin. Not: Öğrencilere plastiği nasıl güvenli bir şekilde kesilebileceğinin gösterilmesi gerekebilir.

05

Elinizde bulunan en az dört plastik nesne üzerindeki sembolere dikkat ederek bunları aşağıda yer alan çalışma bölümlerine kaydedin. Karşılaştırmalı testleri tamamlayarak sonuçlarınızı kaydedin.

Plastik bilgi çizelgesini kullanarak, seçmiş olduğunuz plastiğin adını çalışma bölümüne kaydedin.

Ö R N E K L E M	Plastik parçanın üzerine basılmış bir sembol var mı? Gözlemlerinizi aşağıya çizin.	Plastiğin tam adı nedir? Size yardımcı olması için plastik bilgi tablosunu kullanın.	Yarı saydam mı, saydam mı yoksa opak mı?	Plastiği büküğünüz zaman ne oldu? Esnek mi yoksa sert ve bükülmesi zor mu?	Çizik atınca ne oldu? Temiz bir şekilde mi kesiliyor yoksa kesimin üzerinde beyaz izler var mı?	Suda yüzüyor mu?
1						
2						
3						
4						



 Kullanım Alanları	 • İçecek şişeleri • İlaç şişeleri • Halatlar • Kıyafetler • Halı elyafları	 • Süt şişeleri • Şampuan şişeleri • Sabun şişeleri • Çamaşır suyu şişeleri • Deterjan şişeleri	 • Gıda dışı şişeler • Borular • Pencereler	 • Sterç filmler • Sandviç kutuları • Plastik torbalar • Sıkılabilir ürün şişeleri	 • Yoğurt kapları • Margarin Kutuları • Plastik şişe kapakları	 • Kağıt ardaklar • Plastik çatal-bıçaklar • Paketleme köpüğü	 • Biberonlar • Kompakt diskler • Damacanalara
 Plastik Türü	 PET Polietilen Tereftalat	 HDPE High Density Polietilen	 PVC Poli Vinil Klorür	 LDPE Low Density Polietilen	 PP Polipropilen	 PS Polistiren	 Diğer Çeşitli Plastikler
 Özellikler	• Şeffaf ve sert bir plastik türüdür	• Sıradan beyaz veya renkli	• Sert ve katı bir plastik türüdür	• Yumuşak ve esneyebilen bir plastik türüdür	• Sert fakat esneyebilen bir plastik türüdür	• Yumuşak ve esneyebilen bir plastik türüdür	• Akrilik ve naylon dahil diğer tüm plastik türleridir
 Geri Dönüşüm Oranları	 Çoğunlukla Dönüştürülür Kaldırım kenarı geri dönüşüm programlarının çoğu tarafından toplanmaktadır.	 Çoğunlukla Dönüştürülür Kaldırım kenarı geri dönüşüm programlarının çoğu tarafından toplanır fakat bazen yalnızca boyutlu şişeler geri dönüştürülür.	 Genellikle Dönüştürülür Kaldırım kenarı programlarında sıklıkla geri dönüştürülmez ama Avrupa PVC endüstrisinde VinylPlus gibi programlar yoluyla yaygın olarak geri dönüştürülür.	 Genellikle Dönüştürülür Kaldırım kenarı programlarında sıklıkla geri dönüştürülmez fakat bazı ülkeler tarafından kabul edilir. Plastik alışveriş torbaları, geri dönüşüm için bir çok markete geri götürülebilir.	 Nadiren Dönüştürülür Bazı kaldırım kenarı programlarında geri dönüştürülür.	 Nadiren Dönüştürülür Bazı kaldırım kenarı programlarında geri dönüştürülür.	 Nadiren Dönüştürülür Önceden geri dönüştürülmezdi fakat kaldırım kenarı programları tarafından kabul edilmeye başladı.



İsim _____

Tarih _____

BİLİMSEL NOTLAR

Plastiklerin üzerindeki semboller ne hakkında olabilir, tahminlerin nelerdir?

Bilgi çizelgesi ve oluşturduğun test tablosundan yararlanarak farklı plastik türleri arasındaki benzerlikler ve farklılıklar nelerdir? Düşüncelerini yaz ve gözlemlerin/tahminlerin hakkında bir çizim yap.

TAHMİNLERİM

Bir resim çiz ve plastiklerle ilgili tahminlerini anlat. Neler olmasını bekliyorsun?

GÖZLEMLERİM

Bir resim çiz ve plastik cinsleri gözlemlerini paylaş. Neler oldu?

Neler Oluyor?

Gerçek hayatta plastięi ister elle ister mekanik olarak ayırın, plastiklerin yeniden kullanım veya geri dönüşüm potansiyelini en üst düzeye çıkarmak için yapıldıkları polimere yani plastięin cinsine göre sınıflandırılırlar.

Farklı plastiklerin, bize yapıldıkları polimerleri ve geri dönüştürölüp dönüştürölemeyeceklerini anlatan farklı sembolleri vardır. Ayrıştırma tesislerinde, plastikler, geri dönüştüröldükten sonra bu malzeme için en büyük finansal getiriye ve potansiyel kullanım aralığını sağladığından, yapıldıkları polimerlere yani plastięin cinsine göre ayırma işlemleri yapılır.



Çöp Adam Animasyon Firması

"PROBLEM DURUMU"



Bir plastik şişesinin hikayesini anlatan yazın oldukça beğeni topladı. **Çöp Adam Firması** yetkilileri ise bu hikayeni "**topluma hizmet projesi**" kapsamında değerlendirmek istiyor. Böylelikle hem toplumun plastik atıklar konusunda bilinçlendirmeyi hem de firmanın sosyal reklamını yapmayı amaçlıyorlar.

Bunun için yazdığın hikayeyi temel alarak düşük bütçeli bir stop motion animasyonu hazırlamalısın. Prodüksiyonda geri dönüştürülebilir materyaller kullanman hem bütçe açısından hem de vermek istediğin mesaj yönünden daha etkili olabilir. Haydi başlayalım!



Stop motion animasyonu (ayrıca stop frame animasyonu olarak da adlandırılır) hareket etmeyen nesneleri bize hareket ediyormuş gibi gösteren bir film yapım tekniğidir.

Temel animasyon süreci, nesnelerinizin veya karakterlerinizin fotoğrafını çekmeyi, onları hafifçe hareket ettirmeyi ve başka bir fotoğraf çekmeyi içerir. Görüntüleri arka arkaya oynattığınızda, nesneler veya karakterler kendi başlarına hareket ediyormuş gibi görünür.

ARAŞTIRMAYA BAŞLA VE VİDEOLARA GÖZ AT:

Peki bir stop motion animasyonu için ilk olarak ne yapmak gerekir? veya nelere dikkat etmek gerekir? Bunun için küçük bir başlangıç olması adına aşağıda yer alan kare kodları kullanarak video linklerine ve makalelere erişim sağlayabilirsin.

EASY STOP MOTION
ANIMATION FOR BEGINNERS



STOP-MOTION WITH
ONLY A PHONE APP



DIY STOP-MOTION



Çöp Adam Animasyon Firması

"PROJE DOSYASI"

SORUNU TANIMLA VE ANALİZ ET



OLASI ÇÖZÜMLER BUL VE EN İYİSİNİ SEÇ

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MATERYALLER

Çöp Adam Animasyon Firması

"PROJE DOSYASI"

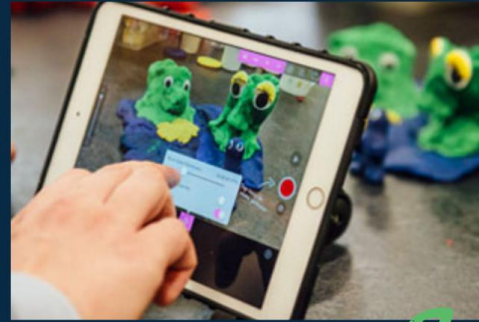
BİR ORNEK YAP VE BUNU TEST ET



PLANLANAN VE TAMAMLANAN PROSEDÜRLER

TASLAK ÇİZİM

(Animasyon sahnelerini
belirlemek için için ekte
yer alan hikaye şablonunu
kullanabilirsin)



Çöp Adam Animasyon Firması

"ÜRÜNÜ PAYLAŞ"

Bu bölüm de bulduğun çözümleri ve geliştirdiğin stop-motion animasyonu hakkındaki detayları **Çöp Adam Animasyon** firması yetkilileriyle paylaşmalısın. Bunun için proje dosyasını ve ürün görsellerini öncesinden öğretmenine veya arkadaşlarına paylaşarak ürününü değerlendirebilir ve böylece daha iyisini düşünebilirsin.

Ayrıca proje sunumunu ve stop-motion animasyon videonu **ncengiz@turkiyemaarif.org** adresine göndererek değerlendirmeye katılabilir ve çalışmanın sosyal medya platformlarında paylaşılmasını sağlayabilirsin.



3 Doğayı Kirletmeden Su Isıtalım

Genel Bakış:

Oyun oynadığın uzun bir günün ardından güzel, sıcak bir duş almak veya banyo yapmak oldukça rahatlatıcı ve eğlenceli olur değil mi? Eminim evdeki duş veya banyodaki sıcak suyun nasıl ısındığını merak etmişsindir. Su ısıtıcıları doğal gaz veya elektrikle çalışır. Peki ya doğayı kirletmeden suyu ısıtmanın başka yolları var mıdır? Bunun için Güneş'i kullanmaya ne dersin? Bu bilim aktivitesi ile, birlikte Güneş enerjisinden yararlanarak en verimli şekilde su ısıtmayı deneyeceğiz. Haydi başlayalım!

Gerekli Malzemeler:

- ❑ 1 adet Strafor yalıtım paneli, (60cm genişliğinde X 120 cm uzunluğunda X 2,5 cm kalınlığında)
- ❑ Alüminyum folyo (1 rulo)
- ❑ 9 adet Plastik torba; kalınlığı yaklaşık 2 mm, çöp torbaları gibi torbalar (Plastik poşetler 3 farklı renkte olmalıdır. Siyah çöp poşetleri, beyaz çöp poşetleri ve başka bir renk çöp poşeti kullanmalısınız. Torbaların aynı boyutlarda olması gerekmez, ancak hepsi 2 litre (L) su tutacak kadar büyük olmalı ve çok benzer kalınlıklarda (yaklaşık 2 mm) olmalıdır.)
- ❑ Makas ve Bant
- ❑ 3 adet Termometre
- ❑ 1 adet 2-L kap; temiz bir 2-L plastik şişe iş görecektir.
- ❑ Mutfak ipi, pamuk
- ❑ Kronometre



01

Strafor panelini alın ve büyük bir yüzeyini alüminyum folyo ile kaplayın. Alüminyum folyoyu, Strafora sıkıca tutturulacak şekilde bantlayın.

02

3 farklı renkte plastik poşet torba alın ve alt kısımlarına makasla küçük bir delik açın. Delik, bir termometrenin içinden geçebileceği kadar büyük olmalıdır.

03

Torbayı, su delikten sızmayacak şekilde, termometrenin etrafından bantlayın.

04

Şimdi 2-L plastik şişe veya kabı suyla doldurun. Suyu torbalardan birine boşaltın. Havayı dikkatli bir şekilde torbanın dışına sıkın ve kapatın. Bir yetişkinin bu adımda size yardımcı olmasını sağlayın. Makas kullanarak ekstra plastiği üstten kesin.



05

Adım 4'ü diğer renkli plastik torbalar için tekrarlayın. Üç farklı renkte güneş kolektörünüz hazır olmalıdır.

06

Alüminyum folyo kaplı paneli tam güneş ışığına yerleştirin. Üç renkli güneş kolektörünüzü yan yana folyo kaplı panelin üzerine yerleştirin. Güneş kolektörlerinin hepsi Güneş'te olmalı ve hiçbir gölgede olmamalıdır. Deney ile ilgili tahminlerinizi Bilimsel Notlar bölümünde yazın/çizin.

Her torbadaki suyun sıcaklığını kontrol edin. Termometrelerin her birini okuyun ve aşağıdaki gibi bir veri tablosuna kaydedin. Suyun başlangıç sıcaklığını not almak bu aşamada oldukça önemli.

Güneş Kolektörü Rengi*	Test	Suyun Sıcaklığının Belirli Aralıklarla Ölçülmesi (°C)				
		Başlangıç	15 dakika sonra	30 dakika sonra	45 dakika sonra	60 dakika sonra
Siyah	1					
	2					
	3					
Beyaz	1					
	2					
	3					
Turuncu	1					
	2					
	3					

*Güneş Kolektörleri için yazılan renkler öneri niteliğindedir. Farklı renklere plastik torbalar kullanılabilir.



07

Üç kolektörü 15 dakika güneş ışığı altında bekletin. 15 dakika süre ile kronometreyi kullanın. 15 dakika sonra, termometrelere bakın ve su sıcaklığını tabloya kaydedin.

08

Toplam 60 dakika boyunca her 15 dakikada bir su sıcaklıklarını kaydetmeye devam edin.

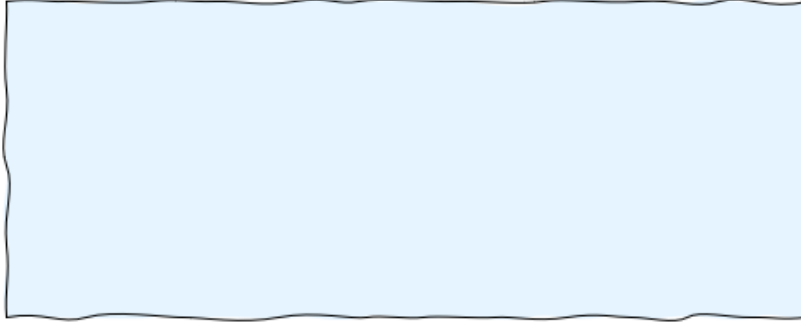
09

Sonuçlarınızın tekrarlanabilir ve doğru olduğundan emin olmak için 2-8 arasındaki adımları diğer plastik torbalarla iki kez daha tekrarlayın. Her zaman gözlemlerinizi not alın.

10

Grafik kâğıdı veya [Create a Graph](https://nces.ed.gov/nceskids/createagraph/) sitesini kullanarak verilerinizin bir grafiğini oluşturun. Bir çizgi grafiği oluşturun ve X eksenini zamanı (dak.) ve Y eksenini sıcaklığı (°C) gösterecek şekilde isimlendirin. Bu grafikte, her torba rengi için bir satır olmak üzere üç satır olmalıdır. Suyun nihai sıcaklığı ile torbaların rengi arasında nasıl bir ilişki var? Hangi renk suyu en çok ısıttı ve hangi renk suyu en çok serin tuttu? Oluşturduğunuz grafikten yararlanarak bu soruları yanıtlayın. Sonuçlarınızı öğretmeniniz ve arkadaşlarınızla paylaşın.

Siteye erişim linki: <https://nces.ed.gov/nceskids/createagraph/>



İsim _____

Tarih _____

BİLİMSEL NOTLAR

Beklediğinden farklı neler oldu? Neler gözlemledin? Güneş kolektörleri gerçekten işe yarıyor mu? Torbanın rengi suyun ne kadar ısındığını etkiler mi? Düşüncelerini yaz ve gözlemlerin/tahminlerin hakkında bir çizim yap.

TAHMİNLERİM

Bir resim çiz ve deneyle ilgili tahminlerini anlat. Neler olmasını bekliyorsun?

GÖZLEMLERİM

Bir resim çiz ve gözlemlerini paylaş. Neler oldu?

Güneş Enerjisi Sistemi (GES)

"PROBLEM DURUMU"



Masumlar Apartmanı sakinleri bu yıl son zamanlardan sonra elektrik faturalarını düşürmek istiyorlar. GES firması çalışanı olarak apartman yöneticisi Ali Rıza beye bir teklif dosyası hazırlamalısın. Aile apartmanının toplam enerji ihtiyacı 15000w ve 75m2lik apartmanın çatı alanını bunun için kullanmak istiyorlar. Türkiye'nin en sıcak şehirlerinden biri olan Antalyada yaşadıklarını hatırlatmam gerek. Antalyadaki güneşlenme hesaplamaların için Türkiye Güneş Atlası faydalı olabilir. Farklı firmalarında kendi tekliflerini sunacakları bu ihaleyi kazanmaya başlamanın yollarını aramanın zamanı geldi.

Haydi başlayalım!



ARAŞTIRMAYA BAŞLA VE VİDEOLARA GÖZ AT:

Güneş enerjisi sistem fiyatı/maliyeti en düşük sistemler olduğundan günümüzde tercih edilen yenilebilir enerji kaynaklarının başında gelmektedir. Ayrıca güneş enerjisi sistemleri sınırsız, temiz, depolaması kolaydır. Trafik ışıklarından fabrika çatılarına kadar GES sistemini bir çok alandan görmeniz mümkündür.

GES (GÜNEŞ ENERJİ
SİSTEMLERİ) - VAN



CW ENERJİ ÇATI ÜSTÜ
MİKRO GÜNEŞ ENERJİ
SANTRALİ (GES) KURULUMU



DÜNYANIN EN BÜYÜK
ÇATI ÜSTÜ GÜNEŞ
ENERJİSİ SANTRALİ



Güneş Enerjisi Sistemi (GES)

"PROJE DOSYASI"

SORUNU TANIMLA VE ANALİZ ET



OLASI ÇÖZÜMLER BUL VE EN İYİSİNİ SEÇ

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MATERYALLER

Güneş Enerjisi Sistemi (GES)

"PROJE DOSYASI"

BİR ORNEK YAP VE BUNU TEST ET



PLANLANAN VE TAMAMLANAN
PROSEDÜRLER

TASLAK ÇİZİM

(En iyi güneş fırını tasarımı
belirlemek için ekte
yer alan tasarım şablonunu
kullanabilirsin)



Güneş Enerjisi Sistemi (GES)

"ÜRÜNÜ PAYLAŞ"

Bu bölüm de bulduğun çözümleri ve geliştirdiğin en iyi güneş paneli tasarımının hakkındaki detayları paylaşmalısın. Bunun için proje dosyasını ve ürün görsellerini öncesinden öğretmenine veya arkadaşlarına paylaşarak ürününü değerlendirebilir ve böylece daha iyisini düşünebilirsin.

Ayrıca proje sunumunu ve en iyi güneş fırını tasarım görsellerini/videoyu **ncengiz@turkiyemaarif.org** adresine göndererek değerlendirmeye katılabilir ve çalışmanın sosyal medya platformlarında paylaşılmasını sağlayabilirsin.



PUBLICATIONS FROM THE THESIS

Conference Papers

1. Cengiz, N., Ünal, H., & Topçu S., M. (June, 2023) The role of engineering design in environment-themed STEM activities: an example of teachers' professional development. *INER- 1st International 21st Century Educational Research Congress, Turkey*

