**Araştırma Makalesi/Research Article[[1]](#footnote-1)**

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**Failure analysis and continual improvement in the engineering design process**

Mühendislik tasarım sürecinde hata analizi ve sürekli iyileştirme

**Ad Soyad** , **Ad Soyad , Ad Soyad**

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## Abstract

**Türkçe yazılan makalelerde Türkçe ve İngilizce özet, İngilizce yazılan makalelerde İngilizce ve Türkçe Özet yer almalıdır.**

STEM education, which means integrated thinking, attracts the attention of early childhood educators and researchers. Engineering education, which naturally serves STEM integration, contributes to children’s problem-solving skills with failure analysis and continual improvement habits of mind. Children need adult support in this process due to their developmental characteristics. This study focuses on the roles of teachers in situations where children fail to solve the problems they encounter in the engineering design process. In this direction, the research was car- ried out with a case study. The participants were 17 preschool teachers working in southwestern Turkey and 255 children in their classes. The data for the study were collected through observation and a semi-structured interview protocol. The data were analyzed by content analysis. According to the results, teachers facilitated failure analysis and continual improvement processes in the problems faced by children by encouraging them to rethink the problem, encouraging them to persist, and inviting communication and cooperation with friends. The findings highlight teacher encouragement as important in children’s failure analysis and continual improvement processes.

**Keywords:** Early childhood, teachers’ roles, failure analysis, continual improvement.

## Öz

Bütünleşik düşünme anlamına gelen STEM eğitimi, erken çocukluk eğitimcileri ve araştırmacıların dikkatini çekmektedir. Doğal olarak STEM entegrasyonuna hizmet eden mühendislik eğitimi, başarısızlık analizi ve zihnin sürekli iyileştirme alışkanlıkları ile çocukların problem çözme becerilerine katkıda bulunmaktadır. Çocuklar, gelişimsel özellikleri nedeniyle bu süreçte yetişkin desteğine ihtiyaç duyarlar. Bu çalışma, çocukların mühendislik tasarım sürecinde karşılaştıkları problemleri çözemedikleri durumlarda öğretmenlerin rollerine odaklanmaktadır. Bu doğrultuda araştırma bir vaka çalışması ile yürütülmüştür. Katılımcılar, Türkiye'nin güneybatısında çalışan 17 okul öncesi öğretmeni ve sınıflarındaki 255 çocuktur. Çalışmanın verileri gözlem ve yarı yapılandırılmış görüşme protokolü yoluyla toplanmıştır. Veriler içerik analizi ile analiz edilmiştir. Sonuçlara göre öğretmenler, çocukları sorunu yeniden düşünmeye teşvik ederek, ısrarcı olmaya teşvik ederek ve arkadaşlarıyla iletişim ve iş birliğini davet ederek, çocukların karşılaştıkları problemlerde başarısızlık analizini ve sürekli iyileştirme süreçlerini kolaylaştırmışlardır. Bulgular, öğretmen teşvikinin çocukların başarısızlık analizi ve sürekli iyileştirme süreçlerinde önemli olduğunu vurgulamaktadır.

**Anahtar Kelimeler:** Öğretmenlerin roller, başarısızlık analizi, sürekli iyileştirme.

# Introduction/Giriş

With the beginning of the twenty-first century, the world is transforming fields such as education, trade, economy, technology, and social structure. Increasing globalization with scientific innovations, labor demands, and economic competition in new fields pushes the competencies and skills expected from individuals into question (Wilmarth, [2010](#_bookmark52)). At this point, two skill sets that continue to attract the attention of researchers in the literature are highlighted: 21st-century and life skills (Kennedy & Odell, [2014](#_bookmark16); Papacharisis et al., [2005](#_bookmark28); Wagner, [2008](#_bookmark51)). 21st-century skills refer to the skills an individual needs to cope with difficulties and contribute to the progress and development of society (Kennedy & Odell, [2014](#_bookmark16); Lai & Viering, [2012](#_bookmark18)). Wagner ([2008](#_bookmark51)) stated that 21st-century skills such as critical thinking, cooperation, problem-solving, leadership, adapting to the environment, entrepreneurship, taking initiative, effective oral and written communication, analyzing information, curiosity, and imagination are essential.

Life skills are another set of skills as crucial as 21st-century skills. Life skills are the ability to function under pressure, solve problems, set goals, communicate, cope with success and failure, work in a group, and receive feedback (Pacharisis et al., 2005). Life skills are adaptive and positive behaviors that enable individuals to deal effectively with the demands and challenges of daily life. UNESCO ([2008](#_bookmark47)) defines life skills as “psycho-social skills that can be learned and applied, such as self-aware- ness, problem-solving, critical thinking, and interpersonal skills.” Life skills are com- petencies that facilitate an individual’s physical, mental, and emotional well-being.

## Engineering design process (EDP)

People must develop tools, machines, materials, and processes to solve problems (Bers et al., [2013](#_bookmark2)). Engineers collaborate to solve a problem that people need (Lange et al., [2019](#_bookmark19)) and define their work as “designing within limitations” (Cunningham, [2018](#_bookmark7); Cunningham & Hester, [2007](#_bookmark8)). Engineering design is the planning, organization, development, testing, production, and operation of products that fulfill a desired function within the specified criteria and constraints through scientific and mathematical principles (Lange et al., [2019](#_bookmark19)). Due to the rise of STEM education in early childhood education, in recent years, researchers have focused on integrating engineering into preschool classrooms and supporting children’s engineering habits of mind (EHoM) (Bagiati & Evangelou, [2015](#_bookmark1); Lippard et al., [2018](#_bookmark20); Van Meeteren & Zan, [2010](#_bookmark48)).

# Methods/Yöntem

## Research design/Araştırma deseni

This research was conducted in the tradition of the qualitative case study. A case study is an in-depth description and examination of a limited system (Merriam, [2009](#_bookmark23); Patton, [1990](#_bookmark29)). According to Yin ([1993](#_bookmark53)), a qualitative case study is suitable to cover the contextual conditions of the phenomenon under study. This study examined the failure analysis and continual improvement habits of mind that children use while solving problems in the EDP in the context of teachers’ facilitator roles.

## Participants and research context/Katılımcılar

In this study, participants were determined by the criterion sampling method, one of the purposeful sampling types. According to Patton ([1990](#_bookmark29)), critical situations can be a source for criterion sampling because they are rich in information. In this study, the critical situation consists of teachers who apply the EDP, observe the children during the activity, and support them in the problem-solving processes they encounter. Agreeing to participate in professional development (PD) in early engineering education and integrating their practice with children in early engineering education were accepted as criteria for participation in the research. After explaining the purpose and process of the research, 17 early childhood teachers voluntarily participated in the study. The participants work in a public preschool in a province in southwestern Turkey. Descriptive data about the participants is explained in Table [1](#_bookmark0).

|  |
| --- |
| **Table 1** Teachers and Children Distribution of Demographic Information |
|  | Demographic Variables |  | F | % |
| **Teachers** | Gender | Female | 17 | 100 |
|  |  | Male | 0 | 0 |
|  | Age | 20–24 years old | 8 | 47.06 |
|  |  | 25–29 years old | 3 | 17.65 |
|  |  | 30–34 years old | 4 | 23.53 |
|  |  | 35–39 years old | 2 | 11.75 |
|  | ProfessionalExperience | 1–5 years | 9 | 52.94 |
| 6–10 years | 5 | 29.41 |
|  |  | 11–15 years | 3 | 17.65 |
| **Children** | Gender | Girl | 132 | 51.77 |
|  |  | Boy | 123 | 48.23 |
|  | Age | 6-year-olds | 87 | 34.12 |
|  |  | 5-year-olds | 115 | 45.10 |
|  |  | 4-year-olds | 53 | 20.78 |
|  | Number of years in early childhood institutions | First year in preschool | 193 | 75.67 |
|  | Second year and above in preschool | 62 | 24.33 |

As seen in Table [1](#_bookmark0), all the participants were women. Participants are predominantly between 20 and 24 (*N* = 8). Most participants have 1–5 years of professional experience (*N* = 9). In addition, an average of 15 children are in the participants’ classrooms. Three teachers have 16 children in their classroom, five have 15 children, seven have 17 children, and two have 13 children. The participating children comprised 132 girls and 123 boys aged between 4 and 6 years. The majority of children (45.10%) are in the 5-year-old group. Two hundred nine participating children attend a half-day preschool, and 46 follow a full-time preschool. None of the children received special education or mainstreaming. All of the children came from families where their parents lived together.

# Findings/Bulgular

The teachers guided the children to overcome the challenges during the EDP. The encouragement of the teachers made it easier for the children to look at problems from different perspectives and solve them. Teachers seem to assist children in failure analysis and continual improvement, taking on three key roles: (1) encouragement to rethink the problem; (2) encouragement of patience and persistence; (3) an invitation to communication and collaboration.

## Encouragement to rethink the problem

Teachers emphasized that when children experience failure in their designs, they try many ways to motivate them to solve problems. According to teachers, these ways encouraged children to think about the problem again and try the solutions they produced. Additionally, teachers asked the children to share the solutions they found. According to teachers, the sharing process led children to make new experiments, think, and find creative solutions. T4 emphasized her thoughts on this issue as follows:

I tell the child to think so that he can notice the part of his work that has failed. I want him to consider the reasons for the failure and share the solutions he discovered. As children come up with ideas, they are very willing to experiment (T4).

# Discussion and implication/Tartışma

This study focuses on the roles of teachers in failure analysis and continual improvement processes while solving problems that children encounter in engineering design activities. Children participating in the EDP already acquire many skills (Bustamante et al., [2018](#_bookmark5); Stone-MacDonald et al., [2015](#_bookmark42); Moore et al., [2018](#_bookmark25)). However, the significance of teacher encouragement in failure analysis and continual improvement of children is emphasized to deepen these skills (Dorie & Cardella, [2014](#_bookmark9); Jones & Gearns, [2016](#_bookmark15)). At this point, the aim of the study is meaningful. As seen in the findings, the teachers invited the children to rethink the problem, be patient and insistent, and communicate and cooperate with their peers to motivate them to solve it. These strategies empower children in the face of problems through failure analysis and continual improvement. The zone of proximal development (ZPD) within Vygotsky’s social constructivist understanding sheds light on the subject. The ZPD represents the possible learning a child can achieve when appropriate educational conditions are provided (Schunk, [2014](#_bookmark34)). In addition, it refers to many tasks that the child has not yet accomplished but can achieve with the help of talented people (Vygotsky, [1978](#_bookmark50)). Within the scope of this study, teachers encouraged children to solve problems through their roles in the ZPD in children’s early engineering learning.

Teachers tried to support failure analysis and continual improvement by encouraging children to think again about the problem. In this process, they used protective questions and organized the learning environment. It has been determined that these strategies teachers use encourage children to do failure analysis and continual improvement while solving problems. Using accurate and effective questions in the STEM education process encourages children to deepen their learning and learn more (Bredekamp, [2020](#_bookmark3)). In addition, the materials in the learning centers provide children with the opportunity to develop EHoM by providing opportunities to examine relationships. These opportunities force children to think about the properties and functions of various materials and encourage them to solve problems (Lippard et al., [2018](#_bookmark20)). Rethinking the problem can help us find potential failings. In the literature, it is emphasized that teacher support in the early STEM and engineering education process provides children with the opportunity to test, develops children’s problem- solving skills, and directs children to cooperate (Lippard et al., [2018](#_bookmark20); Simoncini & Lasen, [2018](#_bookmark40)). Therefore, our findings are consistent with the literature.

## Limitations and Future Directions/Sınırlık ve Öneriler

This study has some limitations. First, this study is limited due to the small number of participants. The small number of participants creates a problem for the generaliz- ability of the data obtained. This limitation is mitigated by the fact that this study is qualitative and does not seek to generalize. However, based on this limitation, future quantitative and qualitative studies can be conducted with more prominent partici- pants. Also, before the study, the teachers were involved in a PD process. Therefore, the data obtained were shaped more by the post-PD experiences of teachers than by their routine practices. In order to better capture the current situation, future studies can focus on children’s problem-solving processes without raising any awareness among teachers. In this study, it was determined that the questions asked by the teach- ers to the children helped with problem-solving. Future studies can be carried out to support teachers’ questioning skills. The findings of this study support EHoM. PD programs can be prepared through which teachers can raise awareness on this issue. The findings suggest that fostering optimism in children plays a crucial role in failure analysis and continual improvement. At this point, it is recommended to organize teacher PD. This study focused on teachers’ strategies to encourage children to solve problems encountered during the EDP process. Future studies can focus on children’s problem-solving strategies in the EDP process.

# Conclusion/Sonuç

This study highlights teachers’ strategies to support children’s failure analysis and continual improvement habits of mind during the EDP. As seen in the findings, teach- ers tried to help children in their problem-solving processes by encouraging them to rethink problems, showing patience and determination, and supporting them in com- municating and collaborating with their peers. These strategies helped children make sense of problems and empowered them to engage in failure analysis and continual improvement. Therefore, the findings reveal how teachers contribute to children’s development of problem-solving skills by using EDP in their classrooms. Addition- ally, this study highlights the importance of teachers’ role in supporting students’ failure analysis and continual improvement processes. These findings highlight the importance of engineering education in early childhood and provide perspectives on how teachers can play an influential role in this process.

**Declarations / Beyanlar**

**Etik Kurul İzin Bilgisi:** Bu çalışma Pamukkale Üniversitesi Bilimsel Araştırma Yayın ve Etik Kurulu’nun 16/09/2020 tarihli 93803232-622.02 sayılı kararı ile alınan izinle yürütülmüştür.

**Yazar Çıkar Çatışması Bilgisi:** Yazarlar çıkar çatışması olmadığını beyan eder.

**Yazar Katkısı:** Makale yazarlarının çalışmada katkısı eşit orandadır.

**Katılım Onayı:** Ebeveynlerden ve çocuklardan yazılı ve sözlü onay alınmıştır.

**Yayın Onayı:** Bütün haklarımı temel eğitim dergisine devrettiğimi onaylarım. Makalede geçen ifade ve açıklamalar yazarlara aittir.

**Bilgilendirilmiş Onam:** Tüm katılımcılardan bilgilendirilmiş onam alınmıştır. Tüm katılımcılar ve aileleri çalışmanın amacı, veri toplama araçları ve yöntemi hakkında bilgilendirilmiştir. Katılımcılardan ve ailelerinden hem yazılı hem de sözlü katılım onayı alınmıştır. Tüm katılımcılar gönüllülük esasına göre çalışmaya dahil edilmiştir. Katılımcılar ve aileleri istedikleri zaman çalışmadan ayrılabileceklerinin farkındadır. Başvuru ve veri toplama süreci boyunca katılımcıların mahremiyetini ihlal edecek hiçbir davranış veya sözlü eylemde bulunulmamıştır. Veri işleme sırasında katılımcıların kimlikleri tamamen anonim tutulmuş ve katılımcıların mahremiyeti dikkate alınmıştır.

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**Teşekkür:**

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**APA 7**

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**Türkçe metinlerden sonra Genişletilmiş Uzun Özet istenmektedir (750-1000 kelime)**

# Extended Abstract

**Background**

The concept of communication comes from the Latin root of “communis, communicare” and is considered as a process of trying to understand and interpret the messages participants send to each other by constructing knowledge or symbols (Dökmen, 1998). This concept is described in different ways by many researchers (Adair, 2013; Baltaş & Baltaş, 1992; Cüceloğlu, 2000; Çilenti, 1984; Planalp, 1999).

**Purpose/Hypothesis**

The concept of communication comes from the Latin root of “communis, communicare” and is considered as a process of trying to understand and interpret the messages participants send to each other by constructing knowledge or symbols (Dökmen, 1998). This concept is described in different ways by many researchers (Adair, 2013; Baltaş & Baltaş, 1992; Cüceloğlu, 2000; Çilenti, 1984; Planalp, 1999).

**Design/Method**

The participants of the study consist of 445 students [% 84.7 of girls (n=377) and % 15.3 of boys (n=68)] majoring at faculty of education in Pamukkale University in the academic year 2015-2016. Students’ chronological age was ranging from 19 to 35. In the study, a range of steps were followed in the process of scale development. Before all else the communication skills (Ego Supportive Language, Active-Participative Listening, Self-recognition/Selfdisclosure, Empathy and I-language) were determined in the direction of constructed conceptualized framework by analyzed literature related to communication. Later on, effective communication skills items were written by researchers in the light of relevant literature. After some procedures and ongoing applications, collected data were analyzed for reliability (Cronbach’s alpha coefficient) and validity (item, explanatory and correlation analyses) of the scale and final shape of the scale was formed.

**Results**

The concept of communication comes from the Latin root of “communis, communicare” and is considered as a process of trying to understand and interpret the messages participants send to each other by constructing knowledge or symbols (Dökmen, 1998). This concept is described in different ways by many researchers (Adair, 2013; Baltaş & Baltaş, 1992; Cüceloğlu, 2000; Çilenti, 1984; Planalp, 1999).

**Discussion**

In this study, a new Effective Communication Skills conceptual framework was proposed to evaluate the communication skills in different perspectives and a scale was developed to assess the communication skills proposed in that conceptualization. Accordingly, within the context of conceptualized framework, five effective communication skills were dwelled on which were Ego Supportive Language, Active-Participative Listening, Self-recognition/Self-disclosure, Empathy and I-language. Then, a range of reliability and validity analyzes were conducted through the process.

**Conclusions**

The concept of communication comes from the Latin root of “communis, communicare” and is considered as a process of trying to understand and interpret the messages participants send to each other by constructing knowledge or symbols (Dökmen, 1998). This concept is described in different ways by many researchers (Adair, 2013; Baltaş & Baltaş, 1992; Cüceloğlu, 2000; Çilenti, 1984; Planalp, 1999).

**Author and Affiliations / Yazar ve Bağlantılar**

**Ad Soyad**1, **Ad Soyad2, Ad Soyad3**

Sorumlu yazar **Ad Soyad**

eposta@yildiz.edu.tr

Department of Preschool Education Program, Pamukkale University, Denizli, Turkey, e-mail, ORCID

2 ….

3 ….

1. Sorumlu Yazar Ad Soyad

 eposta@pau.edu.tr

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