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From Idea to Product: A Case Study For Enhancing Transdisciplinary Engineering Education at Azerbaijan Technical University (AzTU)

Fikirden Ürüne: Azerbaycan Teknik Üniversitesi'nde Mühendislik Eğitimin Geliştirilmesine Yönelik Disiplinler Arası Bir Vaka Çalışması

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Abstract

Purpose: *Engineer Enhancement Program (EEP) is centered around transdisciplinary learning, an educational framework designed to exceed traditional academic boundaries in pursuit of comprehensive solutions to real-world problems by integrating of practical industry knowledge with theoretical academic learning. The aim of this study is to show the implementation of practical based enhancement program for interdisciplinary education in engineering.*

Methodology: *In terms of progress evaluation, comprehensive methods have established to assess the technical knowledge level of each participant. This*

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evaluation framework not only measures current competencies but also identifies areas for growth, enabling to tailor the learning experience to maximize each development of students. At the outset of the program, a self-assessment was initiated to establish a baseline of student knowledge. As the program progressed, this assessment was repeated to measure the development of the students' knowledge. The evaluation process included a blend of written tests, peer reviews and performance analytics.

Findings: *In terms of technical knowledge level of the participants; self-assessment reports that showcased the knowledge levels of participants before and after engaging with the program. This comparison highlighted the educational impact of the program. Each role, regardless of its unique demands and challenges, has seen a marked improvement from the initial assessment to the final evaluation. There was a consistency between the mentors' evaluations and the students' self-assessments suggests a high level of objectivity and reliability in the feedback process. Upon the personal feedback of the participants through a series of basic questions about the program; 97,5% of the participants advise the Engineer Enhancement Program to their collegues.*

Implications: *This study provides evidence to the advantage of project-based learning for transdisciplinary competence development by solving complex real-world problems. Results show that the EEP has significantly enhanced the students' learning experience, providing them with a unique edge and a deeper understanding of the aerospace sector. The feedback has been overwhelmingly positive, with a significant majority of students expressing satisfaction with the program's offerings. The success of this pilot program has sparked interest from other educational institutions.*

Limitations: *For the success of the Engineer Enhancement Program, minimum number of the participants needed for design, analysis, avionics, flight science and manufacturing activities of the aircraft is 30. The number of participants involved in the project represents an optimal balance, established on the workload and the project timeline. Table 1 illustrates the distribution of teams according to their specific tasks:*

Table 1. Minimum number of participants per task

ROLE	TASK	NUMBER OF PARTICIPANTS
STRUCTURAL DESIGN	Master Geometry Design	1
	Wing Design	2
	Fuselage Design	2
	Tail Design	1
	Landing Gear Design	2
STRUCTURAL ANALYSIS	Wing Analysis	2
	Fuselage Analysis	2
	Tail Analysis	1
	Landing Gear Analysis	2
AVIONICS	Identification of Flight Critical Equipment	3
	Mission Critical Software Development	3
	Designing System Architecture and Integration	3

FLIGHT SCIENCE	Performance	2
	Aircraft Sizing	2
	Computational Fluid Dynamics	2

As part of the project carried out in collaboration with Azerbaijan Technical University (AzTU) and the National Aviation Academy (NAA), the number of participants was determined to be 37 as a result of the interviews conducted. The role distribution was carried out by taking into account the education the participants received at the univesity. While this led to a higher number of participants in some roles, in others it caused the number of participants to fall below the mimimum required and increased the workload of the participants.

Keywords: *Transdisciplinary learning, Engineering Enhancement Program, product-based practical training.*

Jel Codes:

Özet

Amaç: *Mühendislik Geliştirme Programı (EEP), pratik endüstri bilgisini teorik akademik öğrenmeyle bütünleştirerek, gerçek dünya sorunlarına kapsamlı çözümler bulmak amacıyla geleneksel akademik sınırların ötesine geçmek üzere tasarlanmış, disiplinlerarası öğrenmeyi merkeze alan bir eğitim programıdır. Bu çalışmanın amacı, mühendislikte disiplinlerarası eğitim için pratiğe dayalı bir geliştirme programının uygulanmasını göstermektir.*

Yöntem: *Katılımcıların gelişim değerlendirmesi aşamasında, her katılımcının teknik bilgi seviyesini değerlendirmek için kapsamlı yöntemler oluşturulmuştur. Bu değerlendirme çerçevesi, yalnızca mevcut yetkinlikleri ölçmekle kalmaz, aynı zamanda gelişim alanlarını da belirleyerek, öğrenme deneyimini her öğrencinin gelişimini en üst düzeye çıkaracak şekilde uyarlamayı mümkün kılar. Programın başlangıcında, öğrenci bilgisinin temel bir çizgisini oluşturmak için bir öz değerlendirme başlatılmıştır. Program ilerledikçe, öğrencilerin bilgi gelişimini ölçmek için bu değerlendirme tekrarlanmıştır. Değerlendirme süreci, yazılı testler, akran değerlendirmeleri ve performans analizlerinin bir karışımını içermektedir.*

Bulgular: *Katılımcıların teknik bilgi düzeyleri açısından; programa katılmadan önce ve sonra, katılımcıların bilgi düzeylerini gösteren öz değerlendirme raporları karşılaştırılmıştır. Bu karşılaştırma, programın eğitimsel etkisini vurgulamıştır. Her rol, kendine özgü talepleri ve zorlukları ne olursa olsun, ilk değerlendirmeden son değerlendirmeye kadar belirgin bir iyileşme göstermiştir. Mentorların değerlendirmeleri ile öğrencilerin öz değerlendirmeleri arasında tutarlılık olması, geri bildirim sürecinde yüksek düzeyde nesnellik ve güvenilirlik olduğunu göstermektedir. Katılımcıların program hakkında bir dizi temel soru aracılığıyla verdikleri kişisel geri bildirimler sonucunda, katılımcıların %97,5'i Mühendislik Geliştirme Programını meslektaşlarına tavsiye etmiştir.*

Sonuç ve Katkılar: *Bu çalışma, karmaşık gerçek dünya problemlerini çözerek disiplinler arası yetkinlik gelişimi için proje tabanlı öğrenmenin avantajlarına dair kanıtlar sunmaktadır. Sonuçlar, EEP'nin öğrencilerin öğrenme deneyimini önemli* *ölçüde geliştirdiğini, onlara benzersiz bir avantaj ve havacılık sektörü hakkında daha derin bir anlayış sağladığını göstermektedir. Geri bildirimler son derece olumlu olmuş ve öğrencilerin önemli bir çoğunluğu programın sunduklarından memnuniyetlerini dile getirmiştir. Bu pilot programın başarısı diğer eğitim kurumlarının da ilgisini çekmiştir.*

Sınırlılıklar: *Mühendis Geliştirme Programı'nın başarısı için, uçağın tasarım, analiz, aviyonik, uçuş bilimi ve üretim faaliyetleri için gereken minimum katılımcı sayısı 30'dur. Projeye dahil olan katılımcı sayısı, iş yükü ve proje zaman çizelgesine göre belirlenen optimum bir dengeyi temsil etmektedir. Tablo 1, ekiplerin belirli görevlerine göre dağılımını göstermektedir:*

Tablo 1. Ekiplerin Görevlerine Göre Rol Dağılımları

ROL	GÖREV	KATILIMCI SAYISI
YAPISAL TASARIM	Mastar Geometri	1
	Kanat Tasarımı	2
	Gövde Tasarımı	2
	Kuyruk Tasarımı	1
	İniş Takımı Tasarımı	2
YAPISAL ANALİZ	Kanat Analizi	2
	Gövde Analizi	2
	Kuyruk Analizi	1
	İniş Takımı Analizi	2
AVİYONİK	Uçuş Kritik Ekipmanlarının Belirlenmesi	3
	Görev Kritik Ekipmanlarının Belirlenmesi	3
	Sistem Mimarisi ve Entegrasyonu Tasarımı	3
UÇUŞ BİLİMLERİ	Performans	2
	Hava Aracı Boyutlanması	2
	Hesaplamalı Akışkanlar Dinamiği	2

Azerbaycan Teknik Üniversitesi (AzTÜ) ve Milli Havacılık Akademisi (NAA) iş birliğiyle yürütülen proje kapsamında, yapılan görüşmeler sonucunda katılımcı sayısı 37 olarak belirlenmiştir. Rol dağılımı, katılımcıların üniversitede aldıkları eğitim dikkate alınarak yapılmıştır. Bu durum, bazı rollerde katılımcı sayısının artmasına yol açarken, bazılarında ise katılımcı sayısının gerekli asgari sayının altına düşmesine ve katılımcıların iş yükünün artmasına neden olmuştur.

Anahtar Kelimeler: *Disiplinlerarası öğrenme, Mühendislik Geliştirme Programı, ürün tabanlı uygulamalı eğitim.*

Jel Kodu:

1. Introduction

The industry is increasingly dependent on unique skill sets to foster innovation and maintain a competitive edge in particularly in aerospace area (Lappas 2016, Roy 2022). Concurrently, engineering students are looking towards academic institutions to equip them with the latest technologies and prepare them for a seamless transition into the workforce (Hero 2019, Borah 2021). This situation presents a unique opportunity for academic institutions to reevaluate and realign their educational strategies to meet the demands of both students and the industry (Kilic-Bebek, 2023). The educational curriculum is responsive to the evolving technological landscape and industry requirements by fostering a closer collaboration between academia and industry (Rybnicek, 2019; King, 2020). This collaboration could take various forms, such as industry-sponsored research projects, internships, and curriculum development by professionals actively engaged in the field which is required to ensure transdisciplinary skills enhancement (Ankrah, 2015; Rabb, 2019).

Engineer Enhancement Program (EEP) is an applied extensive training program of Turkish Aerospace Industries (TA) that not only enhances the technical skills of newly graduated engineers but also covers a wide range of practical activities in the aviation field, from conceptual design to flight operations. EEP has been a cornerstone of talent development at TA with approximately 1000 graduated engineers. EEP's approach has been to integrate hands-on experience with cutting-edge theoretical knowledge, fostering an environment where learning directly contributes to the advancements in aerospace technology. In the literature, most of the similar duration trainings consist of only theoretical trainings. However, at the end of EEP, students experience all the steps from design to flight tests of an aircraft with a system engineering approach. It is thought that the training is different and unique in that these processes are completely dependent on the performance of the students and that they produce a product at the end of the training program. The hallmark of EEP is the practical project phase, where participants are tasked with designing an aircraft according to aviation standards. This real-world project experience allows participants to simulate the complete lifecycle of an aircraft project, including the critical steps of Systems Requirements Review (SRR), Preliminary Design Review (PDR), Critical Design Review (CDR), test and validation, manufacturing, and flight testing. EEP is an initiative designed to harness the potential of engineering undergraduates by immersing them in a practical, hands-on project: designing and producing an aircraft within an 18-week timeframe. This program is a unique educational model that can be tailored to meet specific learning outcomes and industry needs and proposes a collaborative initiative between the academic sector and the aviation industry aimed at cultivating a new generation of highly skilled engineers. EEP has recently been honored with the gold medal in the Brandon Hall Group Excellence Awards, specifically in the category of Best Unique or Innovative Learning and Development Program in 2023. (Brandon Hall Group, 2023).

As of 2024, TA extended the reach of the EEP beyond corporate walls to the academic sphere. This initiative was born out of a strategic partnership with Azerbaijan Technical University (AzTU) and National Aviation Academy (NAA). This collaboration marked the first time the EEP was adapted for an academic setting. The core goal is to bridge the gap between academic knowledge and real-world engineering skills, ensuring that engineers are better equipped to meet the evolving demands of the aviation sector by transferring current technology and engineering knowledge from TA to AzTU and NAA.

In industry, projects are managed by project managers. Sub-teams in projects strive to complete the work packages given according to the requirements on time. The general process of EEP is also designed with this structure. In the program, where experienced engineers serve as trainers and mentors, the aim is to combine theoretical knowledge with practical knowledge and create a product with real functionality. Here, rather than an obligation such as passing an exam, they are expected to use the information given to them in the training phase directly in the project phase. Student focus on seeing the big picture by understanding the importance of group work, beyond their individual performance. This valuable initiative aims to not only enhance the educational curriculum but also provide students with valuable hands-on experience that complements their university studies (Beemt, 2020).

2. Method

This section presents an overview of EEP and structured in four main subsections. The program's architecture and implementation are detailed first, followed by participant selection and engineering role placement processes. Then, the evaluation methods for assessing technical knowledge is outlined. The final section complies participant feedback, categorized by survey type.

2.1. Program Architecture and Implementation Details

In this section, firstly the program architecture and implementation details have given with detail information. The whole program consists of three main phases as follows:

- **Phase 1: Common training**

  This phase provides interdisciplinary common trainings by having undergraduate students from different engineering. Moreover, this phase aims to help participants better adapt to the demands of the industry by learning commercial and appreciate methods and aerospace-based vocabulary to enhance their professional skills. In this phase, participants keen to learn the role of the other disciplines and making collaboration in the groups by empowering the ability to discern the strengths and limitations inherent in different academic disciplines.

- **Phase 2: Role based training**

  After the first phase, participants were divided into four primary engineering roles: structural design, structural analysis, flight sciences and avionics & software, aligning with their competencies. This phase encompasses an intensive training program, equipping participants with the necessary skills and knowledge to contribute effectively to the aircraft system's development.

  Second phase places a strong emphasis on participants gaining a deep awareness of the structure of their own disciplines. Such knowledge is invaluable, as it not only anchors students learning in a strong foundation but also primes them for successful interdisciplinary collaboration. In this phase, students able to better communicate their insights and contribute to a richer, more diverse academic discourse by understanding the nuances and methodologies specific to their fields.

- **Phase 3: Project**

Project phase promotes hands-on experiences instead of through classroom-based learning. One of the biggest challenges encountered during the implementation of the program at the university was the destruction of the rote learning system provided by the education system. Since a real project was carried out here and a product was expected to be produced at the end, the fact that the participants used their theoretical knowledge directly on the product pushed the students out of the order they were accustomed to in university conditions.

This phase consists of various technical processes including conceptual design, procurement, production, assembly, integration, and testing activities. 37 number of students studying in different branches came together and worked for a common goal. The students engaged in a series of hands-on activities, conceptual design and simulations, and problem-solving exercises designed to mirror the real-world challenges. Due to the multidisciplinary structure of the program, the students were asked to put aside the individual performance goals they had been accustomed to throughout their lives and focus on the big picture. This is another challenge encountered.

Aircraft system development project is designed to offer students aspiring to work in aeronautical comprehensive experience from design to manufacturing. The concept of this project is to engage participants in a comprehensive journey from the initial idea to the final product, fostering innovation and technical excellence along the way.

Following the conceptual design phase, the project transitions into a series of technical review stages including System Requirements Review (SRR), Preliminary Design Review (PDR) and Critical Design Review (CDR). These stages are designed to simulate a real-world product development life cycle in aerospace industry, providing participants with invaluable insights into the complexities and challenges of aircraft system development. Each review stage serves as a checkpoint to ensure that the project is on track and adhering to the highest standards of engineering excellence.

Upon successful completion of the design and review processes, the participants move on to the manufacturing phase. This hands-on experience allows students to construct the aircraft they have designed, applying practical skills and learning about the manufacturing process. Subsequently, the ground tests rigorously test the aircraft to ensure it meets all necessary safety and performance criteria by professional unmanned air vehicle (UAV) pilot. The culmination of the project is the flight test of the aircraft. This final stage is not only a testament to the hard work and dedication of the participants but also an opportunity to evaluate the aircraft's capabilities in real-world conditions.

2.2. Participant Selection and Placement in Engineering Roles

The process of participant selection and placement into engineering roles is crucial for the success of the program. This subsection delves into the criteria used to identify potential candidates and the systematic approach to match them with roles that best fit their skills and aspirations. It is a dynamic process that adapts to the evolving needs of the program and the participants.

The selection process was meticulous and culminated in the choice of 37 students based on their aptitude and interest in specific roles within the engineering spectrum via face-to-face technical interviews. Of these, 24 students hail from AzTU and 13 from NAA. Table 2 illustrates the academic information of the participants:

Table 2. Academic information of the participants

Participant	Degree	Universty	Department	Role
P1	M.Sc.	AzTU	Weapons and weapons systems production technology	Structural Design
P2	M.Sc.	AzTU	Mechanical engineering	Structural Design
P3	M.Sc.	AzTU	Weapons and weapons systems production technology	Structural Design
P4	M.Sc.	MAA	Aviation equipment maintenance engineering	Avionic & Software
P5	M.Sc.	MAA	Aerospace engineering	Structural Design
P6	M.Sc.	MAA	Aerospace engineering	Structural Analysis
P7	M.Sc.	AzTU	Materials science engineering	Structural Analysis
P8	M.Sc.	MAA	Aviation equipment maintenance engineering	Flight Science
P9	M.Sc.	MAA	Aerospace engineering	Flight Science
P10	M.Sc.	AzTU	Aviation equipment maintenance engineering	Flight Science
P11	M.Sc.	MAA	Aviation equipment maintenance engineering	Avionic & Software
P12	M.Sc.	MAA	Mechatronics and robotics engineering	Avionic & Software
P13	M.Sc.	AzTU	Electronics, Telecommunications and Radio Engineering	Avionic & Software
P14	M.Sc.	AzTU	Electronics, Telecommunications and Radio Engineering	Avionic & Software
P15	Ph.D.	AzTU	Mechanical engineering	Structural Design
P16	Ph.D.	AzTU	Pyrotechnics technology	Structural Design

P17	Ph.D.	AzTU	Transportation and management organization	Structural Design
P18	Ph.D.	AzTU	Mechanical engineering and material processing	Structural Analysis
P19	Ph.D.	AzTU	Physical methods and devices of endoscopy	Structural Analysis
P20	Ph.D.	AzTU	Optotechnics	Structural Design
P21	Ph.D.	MAA	Aviation equipment maintenance engineering	Avionics & Software
P22	B.Sc.	AzTU	Military composite materials engineering	Structural Analysis
P23	B.Sc.	AzTU	Military composite materials engineering	Structural Design
P24	B.Sc.	AzTU	Weapons and Weapon Systems Engineering	Structural Design
P25	B.Sc.	AzTU	Weapons and Weapon Systems Engineering	Structural Analysis
P26	B.Sc.	AzTU	Weapons and Weapon Systems Engineering	Structural Analysis
P27	B.Sc.	AzTU	Weapons and Weapon Systems Engineering	Structural Analysis
P28	B.Sc.	AzTU	Mechatronics and robotics engineering	Structural Design
P29	B.Sc.	AzTU	Mechatronics and robotics engineering	Structural Design
P30	B.Sc.	AzTU	Industrial engineering	Structural Design
P31	B.Sc.	MAA	Aerospace engineering	Structural Design
P32	B.Sc.	MAA	Aerospace engineering	Structural Design
P33	B.Sc.	AzTU	Military communications engineering	Structural Design
P34	B.Sc.	MAA	Aerospace engineering	Structural Analysis
P35	B.Sc.	MAA	Aviation engineering design	Flight Science
P36	B.Sc.	MAA	Aviation engineering design	Flight Science
P37	B.Sc.	AzTU	Military composite materials engineering	Structural Analysis

After the evaluation, the breakdown of roles is as follows: 16 students are poised to contribute to structural design, 10 to structural analysis, 5 to flight sciences, and 6 to avionics and software development.

2.3. Evaluation of Technical Knowledge Level and Teamwork Skills

In terms of progress evaluation, various methods have established to assess the technical knowledge level of each participant. This evaluation framework not only measures current competencies but also identifies areas for growth, enabling to tailor the learning experience to maximize each development of students.

During the training phase, the performance of the students was measured with classical test methods. The tests prepared based on the training were applied to the students immediately after the training and the grades they received were reported to the students. In the project phase, the individual performances of the students were evaluated during the milestones used in aviation such as SRR, PDR and CDR and personal reports were made. The evaluations here were carried out using parameters such as presentation performance, statistics on performing the given tasks, and their adaptation to teamwork. These evaluations were made in two different ways. The first evaluations were made by expert and experienced engineers at the head of the teams. In the second evaluation, the students were asked to score their teammates with the blind review method. Both evaluations were very close to each other and were used as an input for individual performances in the project phase.

At the outset of the program, a self-assessment was initiated to establish a baseline of student knowledge. The assessment was designed to capture the essential information that students are expected to know based on their roles, and this was achieved by transforming these knowledge areas into a series of closed-ended questions. It was imperative for the integrity of the process to communicate to the students that this was not a traditional exam setting but rather a tool to gauge their learning journey. The self-assessment consisting of 20 questions, was developed by the mentor assigned to each role, taking into account the competencies required fort hat specific role. The following items illustrate the type of questions included in the assessment:

Q1. In an aircraft, what does 'master geometry' refer to, and what features does it include?

Q2. Fairing structures designed to ensure aerodynamic continuity across the wing-fuselage-tail regions must provide at least what level of surface continuity (e.g., G0, G1, G2, G3)

To ensure authenticity in responses, students were instructed to only answer questions they felt confident about and to leave questions blank where their knowledge was lacking. This was critical to obtain a true reflection of their understanding without the influence of guesswork.

As the program progressed, this assessment was repeated twice to measure the development of the students' knowledge. The same principles applied during the initial assessment were reiterated, emphasizing that the goal was to see their growth in learning, not to administer an exam. This repetition of the practice provided a clear before-and-after snapshot of their educational advancement. Rigorous evaluation methodologies were systematically implemented throughout the process to highlight that the success of participants is contingent not only on their individual performance metrics but olso on the effectiveness of collobrative team dynamics and successful attainment of defined project deliverables and objectives.

Accordingly, 70% of the participants's success score was derived from individually assessed examinations requiring personal achievement, while the remaining 30% was contingent upon collective objectives related to team success, such as the successful flight of the aircraft and the completion of avionics task. Table 3 illustrates the evaluation criteria and success percentages for the participants:

Table 3. Evaluation criteria and success percentages for the participants

TASK CATEGORIES	PERCENTAGE
MIDTERM	20
FINAL	25
ASSIGNMENTS+PRESENTATION	15
SRR SCORE	4
PDR SCORE	5
CDR SCORE	6
PROJECT LABOR	10
PROJECT HANDBOOK	5
COMPLETION of the AVIONICS TASK	4
FLIGHT TEST	6
100	

INDIVIDUAL SCORE	**70**
TEAM SCORE	**30**

To successfully complete the program, participants was expected to obtain at least 70 points according to the specified evaluation criteria. Table 4 illustrates the evaluation results obtained from a sample of randomly selected participants:

Table 4. Sample assessments of participants

P#	ROLE	MIDTERM (20%)	FINAL (25%)	ASSIGNMENTS+ PRESENTATION (15%)	SRR (4%)	PDR (5%)	CDR (6%)	FLIGHT (6%)	AVIONICS TASK (4%)	PROJECT HANDBOOK (5%)	PROJECT LABOR (10%)	SCORE
P1	Avionic & Software	15	19	15,0	2,0	3,5	4,2	5,0	5,0	4,0	10,0	82,7
P2	Structural Analysis	14,6	18,8	13,5	2,4	3,0	3,6	5,0	5,0	5,0	10,0	80,9
P3	Structural Analysis	15,4	16,3	15,0	2,4	3,0	3,6	5,0	5,0	5,0	10,0	80,7
P4	Structural Design	13,8	20	11,9	2,4	3,0	4,2	5,0	5,0	4,0	10,0	79,3
P5	Structural Design	15	15	14,2	2,4	3,0	4,2	5,0	5,0	4,0	10,0	77,8
P6	Structural Analysis	14,4	18,8	11,0	2,4	3,0	3,6	5,0	5,0	4,0	10,0	77,2
P7	Structural Analysis	11	21,3	11,0	2,4	3,0	3,6	5,0	5,0	4,0	10,0	76,3

2.4. Participants' Feedback

The dual-method approach implemented to gather comprehensive feedback of the program. The feedback is instrumental in understanding the participant experience and ensuring that the program is meeting their needs and expectations. The first method is a survey featuring a series of open-ended questions. This survey was meticulously crafted and distributed to the students with the intention of evaluating the various facets of the program. The open-ended nature of the questions was designed to encourage students to provide detailed and reflective responses, offering qualitative data that could highlight areas of success as well as opportunities for improvement. These questions were constructed in both Turkish and English to overcome the language barrier that may seem to be one of the possible limitations of the program. This study's survey questions are as follows:

Q1. Did you satisfied attending the Engineering Enhancement Program? Please explain from the perspective of your experiences.
Q2. If the Engineering Enhancement Program was repeated, would you engage again? Please explain by giving examples.
Q3. Would you advice the program to your colleagues? Please explain by giving examples.

As the second method, face-to-face interviews were conducted during the final two weeks of the program with the participation of Project Manager Görkem ŞİMŞEK, Project Mentors Şeyma Kahraman and Şehmus Güden, and Administrative Affairs Officer Arzu Karakurt. These interviews served as a platform for students to share their experiences and feedback in a more personal and interactive setting by discussing the outcomes and personal experiences related to the program.

3. Results and Discussion

Aerospace is one of the crucial research areas that requires social and technical competence of solving complex transdisciplinary problems. EEP aims to enable students to face and overcome real-world engineering problems with the approach of transdisciplinary learning by developing their role based professional knowledge. This means that it actively involves discussing and negotiating the values and perspectives of various disciplines to create a more holistic understanding of complex issues. It is not merely about juxtaposing or integrating different disciplines, as seen in multidisciplinary and interdisciplinary approaches, but rather about synthesizing and applying this knowledge in a problem-focused manner. The core of this selected approach is its team-oriented nature, which brings experts together from academia and industry with the aim of fostering an integrative learning environment where theoretical knowledge is continuously tested and refined through practical application (Nancy, 2015; Vries, 2019).

3.1. Evaluation of Technical Knowledge Level and Teamwork Skills

The evaluation process included a blend of written tests, peer reviews and performance analytics. In this section, the main objective has been to establish a robust framework that accurately measures technical and teamwork competencies.

3.1.1. Results of Self-Assessment

The technical evaluation process initiated with identifying the core technical skills requisite for each role within the related teams. To ensure a comprehensive evaluation, a self-assessment methodology that encompassed both theoretical knowledge and practical application has been tailored. Self-assessment reports that showcased the knowledge levels of participants before and after engaging with the program. This comparison highlighted the educational impact of the program.

This innovative approach has been beneficial in several ways. It has encouraged students to self-reflect on their knowledge growth, gaps, fostered an environment of honesty and integrity in self-reporting. It has also promoted a culture of continuous learning and self-improvement among team members to be now more aware of their own skill sets and potential growth areas.

The methodology behind this study involved an initial assessment of knowledge levels prior to the students' engagement with their specified roles. Following a period of active participation and learning, a subsequent evaluation was carried out. The results, which are graphically represented in Figure 1, 2, 3, 4 provide a clear and quantifiable measure of the progress made by each student, segmented by their respective roles within the program. Upon close examination of Figure 1, 2, 3, 4 it is evident that there has been a uniform advancement in knowledge and skills across the board. Each role, regardless of its unique demands and challenges, has seen a marked improvement from the initial assessment to the final evaluation. This is indicative not only of the efficacy of the educational framework employed but also of the students' dedication and adaptability. The growth observed is not merely incremental; it is significant and spans the entire spectrum of roles within the project. This suggests that the learning environment fostered an inclusive and comprehensive approach to knowledge acquisition, where every participant, irrespective of their starting point, was given the opportunity to advance considerably.

Figure 1. Levels of technical knowledge of structural design-based participants before and after program

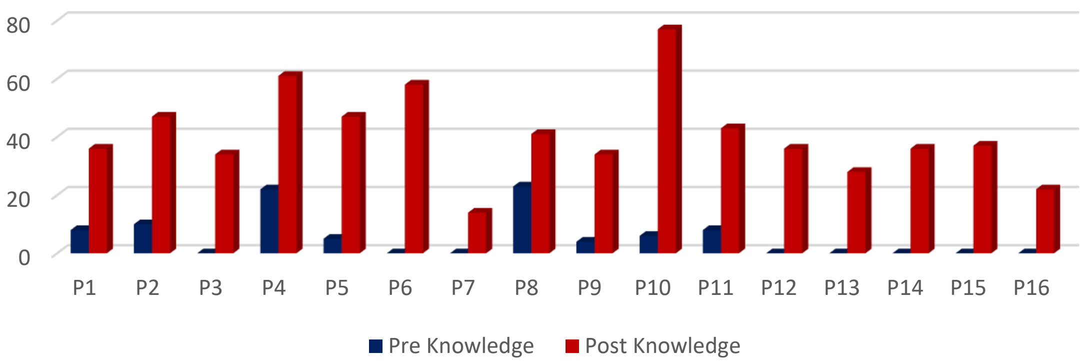


Figure 2. Levels of technical knowledge of structural analysis-based participants before and after program

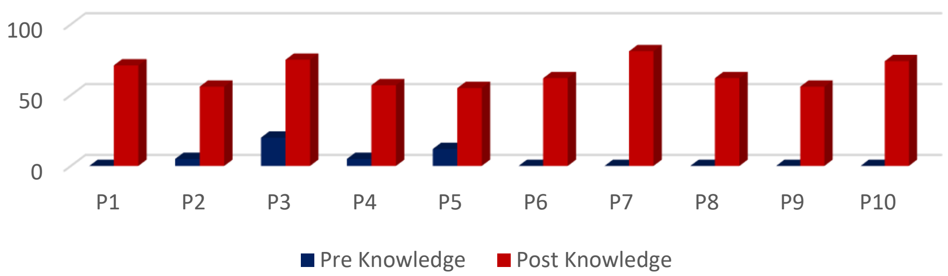


Figure 3. Levels of technical knowledge of avionics and software-based participants before and after program

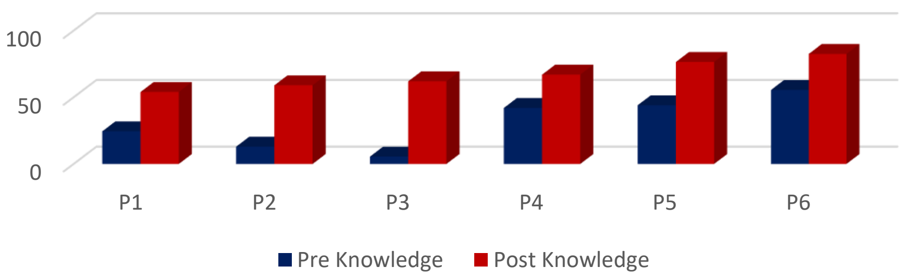
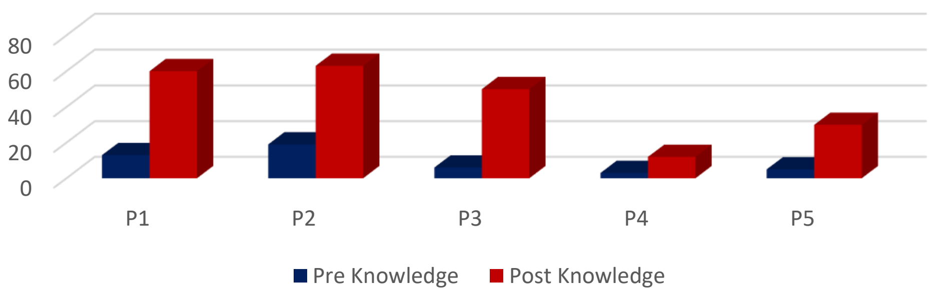


Figure 4. Levels of technical knowledge of flight sciences-based participants before and after program



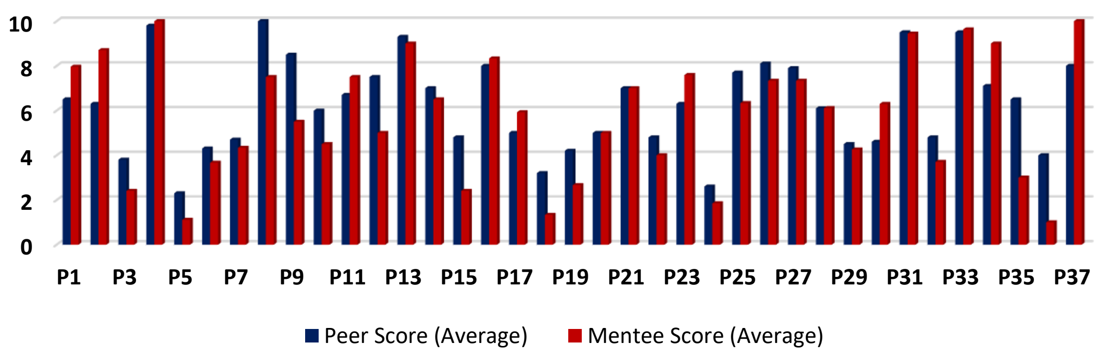
3.1.2. Measurement of Teamwork Skills

The results of teamwork performance evaluations compiled to provide a extensive understanding of the team's strengths and areas for improvement, without singling out any individual unfairly. To illustrate, let's consider a team responsible for structural design, comprising 16 talented individuals. In implementing this evaluation strategy, each member would be tasked with rating the team's performance out of a total score that is one less than the number of team members, in this case, 15. This system ensures that the evaluator is not rating themselves, thereby maintaining objectivity and a focus on the team's overall effectiveness. Peer reviews added a layer of qualitative feedback, offering insights into the working dynamics of the team. Team members were evaluated by their peers on aspects such as communication, leadership, and their ability to contribute constructively to the team's goals. Performance analytics gave a data-driven perspective on each team member's output, efficiency, and the quality of their work.

The core of related approach lies in the dual-layered evaluation system. Engineers, serving as mentors in the program, conduct assessments of their mentees' performance and progress.

Simultaneously, the students are encouraged to engage in peer evaluations, providing feedback on each other's contributions and learning outcomes. The mentors carry out evaluations independently, without prior knowledge of the students' self-assessments. All evaluations are illustrated in Figure 5. The consistency between the mentors' evaluations and the students' self-assessments suggests a high level of objectivity and reliability in the feedback process. This alignment is not a product of chance or mere coincidence; rather, it points to the robustness of the evaluation criteria and the effectiveness of the mentorship guidance provided. Moreover, this parallel in evaluations serves as a strong indicator that the method is not only suitable but also successful in capturing an accurate reflection of the students' abilities and learning advancements. It provides a multi-faceted view of student performance, combining introspective self-assessment with professional external evaluation, thereby offering a comprehensive picture of each student's development.

Figure 5. Peer and mentor score of participants teamwork skills development



3.2. Participants' Feedback

In this part, we engaged in direct dialogue with the participants, gathering their personal feedback through a series of basic questions about the program. This qualitative approach provided in-depth understanding of the participants' perspectives and experiences. The survey, which aimed to gauge the effectiveness and reception of EEP, revealed that the program has met and, in many cases, exceeded the expectations of its participants. An impressive outcome from the survey is that every student except one has indicated their satisfaction with the program. The sole student who expressed reluctance to participate in future iterations did so citing personal family situations, rather than any shortfall in the program itself. Furthermore, the participants unanimously agreed that they would recommend EEP to their peers at their respective universities. This is a testament to the program's value and its potential impact on students across various educational institutions. In terms of expectations, Figure 6 illustrates the positive responses we received. It is clear from this data that the program is not only meeting but often surpassing what the students hoped to gain from their involvement in EEP. The insights gained from these discussions have been invaluable, providing with nuanced perspectives that may not have been fully captured through the survey alone.

Figure 6. Results of program expectations

4. Conclusion

The aim of this study is to show the implementation of practical based enhancement program for interdisciplinary education in engineering. The conception of the interdisciplinary learning-based enhancement program is designed to increase student's core competency on collaborative teamwork and team management. This study provides evidence to the advantage of project-based learning for transdisciplinary competence development by solving complex real-world problems. Results show that the EEP has significantly enhanced the students' learning experience, providing them with a unique edge and a deeper understanding of the aerospace sector. The feedback has been overwhelmingly positive, with a significant majority of students expressing satisfaction with the program's offerings. The success of this pilot program has sparked interest from other educational institutions.

Araştırma ve Yayın Etiği Beyanı

Bu çalışmanın tüm hazırlanma süreçlerinde etik kurallara uyulduğunu yazarlar beyan eder. Aksi bir durumun tespiti halinde Ticari Bilimler Fakültesi Dergisinin hiçbir sorumluluğu olmayıp, tüm sorumluluk çalışmanın yazarlarına aittir. Bu çalışma etik kurul izni gerektirmemektedir.

Yazar Katkıları

1.yazarın katkı oranı: %30, 2. yazarın katkı oranı: %30, 3.yazarın katkı oranı: %30, 4.yazarın katkı oranı: %10.

Research and Publication Ethics Statement

The authors declare that ethical rules are followed in all preparation processes of this study. In case of detection of a contrary situation, Journal of Commercial Sciences has no responsibility and all responsibility belongs to the authors of the study. This study does not require ethics committee approval.

Author Contributions

1st author's contribution rate: 30%, 2nd author's contribution rate: 30%, 3rd author's contribution rate: 30%, 4th author's contribution rate: 10%,

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