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EntrepreneuroDesign: A Novel Framework for Enhancing Final Year Mechanical Engineering Course Efficiency

EntrepreneuroDesign: Makine Mühendisliği Son Sınıf Derslerinin Verimliliğini Artırmak için Yeni Bir Çerçeve

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Abstract
This paper presents an innovative theoretical framework that integrates design thinking principles with entrepreneurial education and Research and Development (R&D) strategies to enhance the efficiency of final-year mechanical engineering courses. The proposed approach, termed "EntrepreneuroDesign," combines the iterative problem-solving methodology of design thinking with entrepreneurial mindset development and industry-driven R&D practices. By restructuring the traditional course curriculum, EntrepreneuroDesign creates a dynamic learning environment that simulates real-world engineering challenges. Students engage in rapid prototyping, market analysis, and collaborative problem-solving, fostering both technical proficiency and business acumen. The framework incorporates three key components: (1) industry-partnered project challenges, (2) iterative design sprints, and (3) entrepreneurial pitch sessions. This structure not only enhances students' engineering skills but also cultivates innovation capabilities and market awareness. Preliminary assessments of the EntrepreneuroDesign framework in a pilot program demonstrate significant improvements in student engagement, project outcomes, and industry-readiness compared to traditional teaching methods. This research aims to contribute to the evolving landscape of engineering education by offering a scalable model that bridges the gap between academic learning and industry demands, potentially developing the preparation of mechanical engineering graduates for the innovation-driven job market.

Keywords: Design thinking, Mechanical engineering education, EntrepreneuroDesign, Innovation pedagogy, Industry-Academia collaboration, Instructional design

Öz
Bu makalede, tasarım odaklı düşünme prensipleriyle girişimcilik eğitimi ve Ar-Ge stratejilerinin bütünleştirilmesiyle, makine mühendisliği son sınıf derslerinin verimliliğini artırmayı amaçlayan yenilikçi bir teorik çerçeve sunulmaktadır. "EntrepreneuroDesign" olarak adlandırılan bu yaklaşım, tasarım odaklı düşüncenin yinelemeli problem çözme yöntemini, girişimci bakış açısı ve endüstri odaklı Ar-Ge uygulamalarıyla bir araya getirmektedir. Geleneksel ders yapısının yeniden kurgulanmasıyla, gerçek dünya mühendislik problemlerinin simüle edildiği dinamik bir öğrenme ortamı oluşturulması hedeflenmektedir. Öğrencilerin hızlı prototipleme, pazar analizi ve işbirlikçi problem çözme süreçlerine aktif katılımı sayesinde hem teknik yetkinliklerinin hem de iş zekâlarının gelişmesi beklenmektedir. Çerçeve; (1) endüstri iş birliğiyle yürütülen proje çalışmaları, (2) yinelemeli tasarım süreçleri ve (3) girişimcilik odaklı sunum oturumları olmak üzere üç temel bileşenden oluşmaktadır. Bu yapı, öğrencilerin mühendislik becerilerinin yanı sıra yenilikçilik kapasitelerini ve pazar farkındalıklarını da artırmayı amaçlamaktadır. Pilot uygulamalardan elde edilen ön bulgular, geleneksel öğretim yöntemlerine kıyasla öğrenci katılımı, proje çıktıları ve endüstriye hazır olma düzeylerinde anlamlı iyileşmeler sağlandığını göstermektedir. Araştırma, akademik öğrenim ile endüstri ihtiyaçları arasındaki boşluğu dolduracak ölçeklenebilir bir çerçeve sunarak, makine mühendisliği mezunlarının yenilikçi iş piyasasına daha iyi hazırlanmasına katkı sağlamayı hedeflemektedir.

Anahtar Kelimeler: Tasarım odaklı düşünme, Makine mühendisliği eğitimi, EntrepreneuroDesign, İnovasyon pedagojisi, Üniversite-Sanayi işbirliği, Öğretim tasarımı

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1. Introduction

Mechanical engineering education faces numerous challenges in today's rapidly evolving technological landscape. One of the primary hurdles is the complexity of core subjects, which demands a high level of mathematical rigor and conceptual understanding from students (Nottingham University Malaysia, 2024). The intensive course load, covering a wide range of topics from thermodynamics to materials science, often overwhelms students and requires effective time management skills (Discover Engineering, n.d.). Moreover, the field's emphasis on practical application necessitates a seamless transition from theoretical knowledge to hands-on experimentation, posing a significant challenge for many learners (Nottingham University Malaysia, 2024). The need for technological proficiency in various software tools and programming languages adds another layer of complexity to the educational journey (Discover Engineering, n.d.). Additionally, the rapidly evolving nature of the industry demands that students stay abreast of emerging technologies, creating a perpetual learning curve (Nottingham University Malaysia, 2024).

In response to these challenges, the concept of EntrepreneuroDesign emerges as an innovative framework that integrates design thinking principles with entrepreneurial education and R&D strategies. This approach aims to enhance the efficiency of final-year mechanical engineering courses by creating a dynamic learning environment that simulates real-world engineering challenges. EntrepreneuroDesign combines the iterative problem-solving methodology of design thinking with entrepreneurial mindset development and industry-driven R&D practices. It incorporates three key components: industry-partnered project challenges, iterative design sprints, and entrepreneurial pitch sessions. This framework not only enhances students' engineering skills but also cultivates innovation capabilities and market awareness, potentially revolutionizing the preparation of mechanical engineering graduates for the innovation-driven job market.

This paper proposes a novel framework, EntrepreneurioDesign, that combines industry partnership, iterative design, and entrepreneurship to improve the efficiency of final-year Mechanical Engineering courses. The aim is to offer an integrated approach that enhances student engagement, project outcomes, and industry readiness by bridging academic learning with real-world engineering challenges.

2. Literature Review

Mechanical engineering education is undergoing significant transformations to meet the evolving demands of industry and society. The traditional curriculum, which has long focused on fundamental principles of mechanics, thermodynamics, and materials science, is now being augmented with interdisciplinary approaches and emerging technologies (Akera, 2017). There is a growing emphasis on integrating computational methods, data analytics, and advanced manufacturing techniques into the core curriculum (Borrego et al., 2014). However, challenges persist in balancing the breadth of knowledge required with the depth of specialization needed in specific areas. A study by Johnson and Ulseth (2016) highlighted the need for more project-based learning and real-world problem-solving experiences to better prepare students for industry demands. Additionally, the COVID-19 pandemic has accelerated the adoption of online and hybrid learning models, prompting educators to rethink pedagogical approaches and assessment methods (Qadir et al., 2020). The Journal of Engineering Education published a study by Borrego et al. (2012) that examined the impact of these changes on student learning outcomes, revealing both opportunities and challenges in adapting mechanical engineering education to the digital age. Despite these advancements, there remains a critical need to address issues of diversity and inclusion within mechanical engineering programs, as the underrepresentation of certain groups continues to be a significant concern (Ro & Knight, 2016).

Design thinking has emerged as a powerful paradigm in engineering education, offering a human-centered approach to problem-solving that complements traditional analytical methods. This approach encourages students to empathize with end-users, define problems more holistically, ideate creatively, prototype rapidly, and test iteratively (Brown, 2008). In the context of mechanical engineering, design thinking fosters innovation and helps bridge the gap between technical knowledge and practical application (Dym et al., 2005). A comprehensive study by Lande and Leifer (2010) demonstrated that integrating design thinking into engineering curricula enhances students' ability to tackle complex, open-ended problems and improves their communication and teamwork skills. The case study by Lande et al. (2010) explored the implementation of design thinking workshops in a mechanical engineering program, revealing significant improvements in students' creative problem-solving abilities and user-centric design approaches. However, challenges remain in fully integrating design thinking across the curriculum, as it often requires a shift in both teaching methodologies and assessment criteria (Goldberg & Somerville, 2014). Some critics argue that an overemphasis on design thinking may come at the expense of technical depth, necessitating a careful balance in curriculum design (Bucciarelli, 2016). Despite these challenges, the growing adoption of design thinking in engineering education reflects a broader recognition of the need to prepare engineers who can navigate complex socio-technical systems and drive innovation in an increasingly interconnected world (Kamp, 2016).

The EntrepreneuroDesign framework demonstrates strong alignment with contemporary STEM education literature and instructional design principles. By integrating iterative design sprints with industry-driven projects, the model embodies key characteristics of integrated STEM education that emphasize authentic problem-solving and interdisciplinary connections (Borrego et al., 2014). This approach resonates with instructional design models like the ADDIE framework, particularly in its cyclical structure of analysis, prototyping, and evaluation phases that mirror modern curriculum development practices (Borrego et al., 2012). The framework's emphasis on constructivist learning through hands-on projects aligns with foundational theories in educational sciences, where situated learning experiences enhance skill transfer to real-world contexts (Dym et al., 2005). Furthermore, the entrepreneurial pitch sessions operationalize progressive assessment strategies advocated in innovation pedagogy, bridging technical competence with market awareness (Kriewall & Mekemson, 2010). These connections position EntrepreneuroDesign as both a pedagogical innovation and a practical implementation of established educational theories within mechanical engineering education.

Entrepreneurial education in STEM fields has gained significant traction in recent years, reflecting a growing recognition of the need to equip students with both technical expertise and business acumen. This trend is driven by the increasing importance of innovation and technology commercialization in driving economic growth (Duval-Couetil et al., 2016). In mechanical engineering, entrepreneurial education often takes the form of specialized courses, startup incubators, and innovation competitions that encourage students to transform their technical ideas into viable business ventures (Byers et al., 2013). A comprehensive study by Maresch et al. (2016) found that entrepreneurship education positively influences students' entrepreneurial intentions, particularly when integrated with their technical studies. In addition, challenges persist in effectively integrating entrepreneurial concepts into already dense STEM curricula and in providing authentic entrepreneurial experiences within academic settings (Neck & Greene, 2011). Critics argue that an overemphasis on entrepreneurship may detract from core technical education, while proponents contend that it enhances students' ability to apply their technical knowledge in real-world contexts (Fayolle, 2013). Despite these debates, the trend towards incorporating entrepreneurial education in STEM fields continues to grow, driven by the belief that future engineers must be equipped not only to solve technical problems but also to identify market opportunities and create value from their innovations (Kriewall & Mekemson, 2010).

Industry-academia collaboration is increasingly vital in mechanical engineering education, as it bridges theoretical knowledge and practical application through initiatives such as joint research projects, internships, and industry-sponsored capstone projects (Perkmann et al., 2013). These partnerships offer significant benefits, including exposing students to real-world challenges, providing access to advanced technologies, and enhancing the relevance of academic research (Ankrah & Al-Tabbaa, 2015). Successful collaborations are facilitated by factors such as trust, clear communication, and shared objectives (Bruneel et al., 2010), while innovative models that integrate industry professionals into curriculum design have been shown to improve student employability and research relevance (Wilson & Taylor, 2024). However, challenges remain in aligning academic and industry priorities, managing intellectual property, and maintaining academic freedom (Perkmann & Walsh, 2009; Slaughter & Rhoades, 2004). Despite these issues, the trend toward closer collaboration continues, as such partnerships are recognized as essential for preparing students for evolving technological demands and fostering innovation in both academia and industry (Etzkowitz & Leydesdorff, 2000).

3. Theoretical Framework: EntrepreneuroDesign

The EntrepreneuroDesign framework is built upon three primary conceptual pillars: design thinking, entrepreneurial mindset, and industry-driven R&D practices. Design thinking provides a human-centered approach to problem-solving, emphasizing empathy, ideation, and iterative prototyping (Brown, 2008). The entrepreneurial mindset fosters innovation, risk-taking, and opportunity recognition, essential skills for engineers in today's dynamic market (Neck & Greene, 2011). Industry-driven R&D practices ensure that academic projects align with real-world challenges and market needs, bridging the gap between theory and application (Perkmann et al., 2013). By integrating these concepts, EntrepreneuroDesign creates a holistic learning environment that prepares students for the complexities of modern engineering practice.

Key components can be outlined as:

Industry-partnered project challenges:

This component involves collaborating with industry partners to develop real-world engineering challenges for students. These projects are carefully designed to reflect current industry needs and technological trends, providing students with authentic learning experiences. Industry professionals serve as mentors, offering guidance and feedback throughout the project lifecycle. This approach not only enhances the relevance of the curriculum but also exposes students to professional networks and potential career opportunities (Ankrah & Al-Tabbaa, 2015).

Iterative design sprints:

Inspired by agile methodologies in software development, iterative design sprints are structured, time-bound periods of intense work focused on specific project goals. These sprints typically last one to two weeks and involve rapid prototyping, testing, and refinement of ideas. This approach encourages students to embrace failure as a learning opportunity and to adapt their designs based on feedback quickly. The iterative nature of these sprints aligns closely with the principles of design thinking, fostering creativity and resilience in problem-solving (Lande & Leifer, 2010).

Entrepreneurial pitch sessions:

Regular pitch sessions provide students with opportunities to present their project progress, innovative ideas, and potential market applications to a panel of industry experts, academics, and potential investors. These sessions not only hone students' communication and presentation skills but also encourage them to consider the commercial viability of their engineering solutions. The feedback received during these sessions helps students refine their ideas and develop a more comprehensive understanding of the business aspects of engineering innovation (Duval-Couetil et al., 2016).

The EntrepreneuroDesign framework represents a pioneering approach in engineering education by uniquely integrating three distinct domains: design thinking, entrepreneurship education, and industry-driven R&D practices. While these concepts have been studied separately in the literature, with design thinking, entrepreneurship education, and industry-driven R&D practices often addressed as distinct domains, their integrated application remains limited and underexplored (Ankrah & Al-Tabbaa, 2015; Duval-Couetil et al., 2016; Dym et al., 2005). Design thinking principles guide problem-definition and ideation, entrepreneurial concepts inform market analysis and value proposition development, and R&D strategies ensure technically sound and innovative solutions through prototyping and testing. This integrated approach enables students to develop creative problem-solving skills, entrepreneurial mindsets, and practical R&D experience simultaneously within the context of real-world industry challenges. The result is a comprehensive educational model that bridges the gap between academic theory and industry practice, preparing students to navigate the complex, interdisciplinary challenges they will face in their future careers as engineers and innovators (Kamp, 2016).

4. Methodology

This study employed a desk-based qualitative research approach, primarily using document analysis and literature review to develop the EntrepreneuroDesign framework. The process began with identifying the challenges in final-year mechanical engineering education and reviewing relevant literature on design thinking, entrepreneurship, and industry-academia collaboration. The content and structure of the proposed framework were determined by systematically analyzing existing models and best practices in the field. The three central components-industry-partnered project challenges, iterative design sprints, and entrepreneurial pitch sessions-were defined based on recurring themes and gaps identified in the literature, as well as feedback from industry partners and alumni. Each stage of framework development was documented and refined through iterative comparison with current educational practices and stakeholder input.

Researcher's role in creation of model:

The EntrepreneuroDesign framework stands out due to the author's unique blend of experiences, which bridges the gap between industry, academia, and entrepreneurship. The author's 25-year industrial career provided deep insights into real-world engineering challenges and market demands, informing the framework's emphasis on practical, industry-relevant projects. This extensive industry background allows for a more nuanced understanding of the skills and competencies that graduates need to succeed in the current job market.

Simultaneously, the author's 12 years of running a company while in academia offered a rare perspective on the intersection of theoretical knowledge and practical application. This dual role enabled the author to identify key areas where traditional engineering education falls short in preparing students for entrepreneurial ventures or innovation-driven careers. The firsthand experience of balancing academic research with business operations informed the framework's integration of entrepreneurial elements into the engineering curriculum. Furthermore, the author's position as an administrator of the department's LinkedIn alumni group provided a unique vantage point to observe the career trajectories of graduates and gather feedback on the evolving needs of the industry. This ongoing connection with alumni facilitated a continuous feedback loop, allowing the framework to adapt to emerging trends and technologies in real-time.

The EntrepreneuroDesign framework is grounded in several well-established theoretical paradigms, enriched by the author's unique combination of industrial, academic, and entrepreneurial experiences. At its core, it draws from constructivist learning theory, which posits that learners actively construct knowledge through experiences and interactions with their environment (Piaget, 1976). This aligns with the framework's emphasis on hands-on, project-based learning, reflecting the author's belief in the importance of practical experience gained from both industry and entrepreneurship. The integration of design thinking is supported by theories of creative problem-solving and innovation, particularly the concept of divergent and convergent thinking processes (Guilford, 1967), which the author has observed as crucial across industrial, academic, and entrepreneurial settings. The entrepreneurial aspects of the framework are underpinned by theories of entrepreneurship education, emphasizing opportunity recognition and value creation (Shane & Venkataraman, 2000), directly informed by the author's concurrent academic and entrepreneurial pursuits. The industry collaboration component is justified by the theory of situated learning, which argues that learning is inherently tied to authentic activities, contexts, and cultures (Lave & Wenger, 1991). This aligns with the author's conviction, based on his 25-year industrial career and ongoing entrepreneurial venture, that exposure to real-world engineering challenges is essential for effective learning. Furthermore, the framework's iterative nature is supported by theories of adaptive expertise, which highlight the importance of flexibility and continuous learning in engineering practice (Hatano & Inagaki, 1986), a principle the author has experienced firsthand in his multifaceted career. By synthesizing these theoretical foundations with practical insights gained from his unique professional journey spanning industry, academia, and entrepreneurship, the author has developed EntrepreneuroDesign as a comprehensive and theoretically robust approach to mechanical engineering education that addresses the complex demands of modern engineering practice.

The EntrepreneuroDesign model integrates three core components-industry-partnered project challenges, iterative design sprints, and entrepreneurial pitch sessions-into a cohesive and cyclical learning process. Industry-partnered project challenges form the foundation, engaging students with authentic, real-world engineering problems developed in collaboration with industry partners and reflecting current technological trends (Ankrah & Al-Tabbaa, 2015). These challenges motivate the subsequent iterative design sprints, which are structured, time-bound periods dedicated to rapid prototyping, testing, and refinement, encouraging students to learn from failure and adapt their ideas (Lande & Leifer, 2010). The outcomes of these sprints provide the basis for entrepreneurial pitch sessions, where students present their progress and innovative solutions to panels of industry experts, academics, and potential investors, receiving feedback that informs the next iteration (Duval-Couetil et al., 2016). This continuous feedback loop mirrors real-world product development cycles, with industry partners often participating in both project challenges and pitch sessions, thus fostering a synergistic environment for innovation, skill development, and market awareness (Kamp, 2016; Kriewall & Mekemson, 2010).

Implementing the EntrepreneuroDesign model in final year courses requires careful planning and coordination. The academic year is typically divided into several cycles, each comprising an industry-partnered project challenge, multiple design sprints, and culminating in an entrepreneurial pitch session. At the beginning of the course, students are grouped into multidisciplinary teams and assigned to a project challenge. Industry partners are engaged early to define project scope and expectations. Throughout the course, regular design sprints are scheduled, with clear milestones and deliverables. Faculty members act as facilitators, providing guidance and technical expertise as needed. Entrepreneurial pitch sessions are scheduled at strategic intervals, allowing for external feedback and project pivots if necessary. To support this model, the curriculum is restructured to include modules on design thinking, entrepreneurship, and professional communication (Neck & Greene, 2011). Assessment strategies are aligned with the model, evaluating not only technical competence but also innovation, teamwork, and entrepreneurial skills. Flexibility is built into the course structure to accommodate the unpredictable nature of real-world projects and to allow for pivots based on industry feedback. This implementation strategy ensures that students gain comprehensive, hands-on experience that bridges the gap between academic learning and industry practice (Sari et al., 2018). The proposed model and framework are presented in Figure 1.

The EntrepreneuroDesign model is structured as a cyclical, project-based learning framework for final-year mechanical engineering courses. It consists of three main, interconnected components:

Industry-Partnered Project Challenges: Students are grouped and assigned real-world engineering problems sourced directly from industry partners. These challenges are selected to reflect current technological trends and industry needs, ensuring relevance and authenticity. Industry mentors are actively involved, providing guidance and feedback throughout the project so that Research and Development (R&D) is based on expertise.

Iterative Design Sprints: Each project challenge is tackled through a series of design sprints, based on the Design Thinking methods, typically lasting 1–3 weeks each. During these sprints, students engage in rapid prototyping, testing, and refinement of their solutions. The iterative nature allows for continuous improvement, with feedback from both faculty and industry mentors.

Entrepreneurial Pitch Sessions: At the end of each cycle, students present their project outcomes and business proposals to a panel of industry experts, academics, and potential investors. These sessions develop students' communication, presentation, and entrepreneurial skills and mindset, and provide critical external feedback to inform further iterations.

The model is implemented over a semester, with multiple cycles (scenarios) possible, each focusing on a different industry challenge. The process is designed to mirror real-world product development and commercialization cycles, bridging academic learning with industry practice.

5. Hypothetical Scenarios

Hypothetical scenario 1: Applying EntrepreneuroDesign in an Innovative Engineering Analysis and Design Course

In this hypothetical scenario, the EntrepreneuroDesign model is implemented in a final-year Mechanical Engineering Innovative Engineering Analysis and Design course. The course partners with a local automotive manufacturer facing challenges in developing lightweight, energy-efficient vehicle components. Students are divided into teams and tasked with designing an innovative suspension system that reduces vehicle weight without compromising performance or safety. The course is structured around three-week design sprints, each culminating in a prototype and pitch session. During the sprints, students apply advanced finite element analysis and computer-aided design tools, while also considering manufacturing constraints and cost implications. Industry mentors provide regular feedback, pushing students to consider real-world factors such as scalability and regulatory compliance. The entrepreneurial pitch sessions involve presenting not only technical solutions but also business models for potential spin-off products. This approach encourages students to think beyond the immediate problem, considering broader market applications for their innovations. By the end of the course, students are expected to develop a comprehensive understanding of the product development cycle, from initial concept to market-ready prototype, while also honing their entrepreneurial skills.

Figure 1
EntrepreneuroDesign Framework

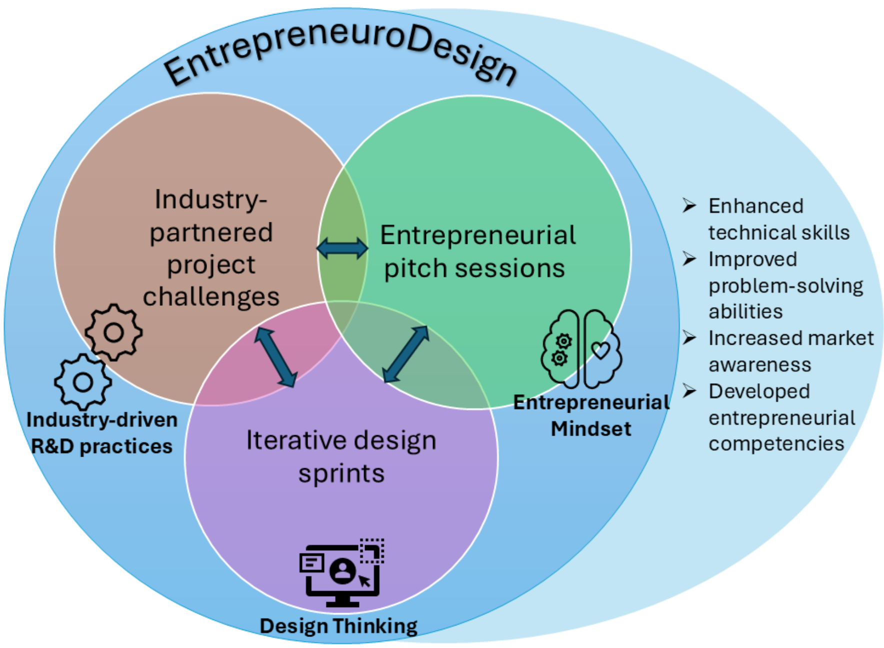

Table 1

EntrepreneuroDesign Model Structure, Sequence, and Outcomes

Phase/Component	Duration (Weeks)	Sequence in Course	Key Activities	Expected Student Outcomes
Industry-Partnered Project Challenge	1	Start of each cycle	Problem definition, team formation, industry briefing	Problem scoping, understanding industry needs
Iterative Design Sprints	2–3 (per sprint)	Repeats 2–4 times	Prototyping, testing, refinement, mentor feedback	Technical proficiency, creative problem-solving, resilience
Entrepreneurial Pitch Session	1	End of each cycle	Presentation to panel, business model development	Communication, market awareness, entrepreneurial mindset

Hypothetical scenario 2: EntrepreneuroDesign in a sustainable engineering project

In this scenario, the EntrepreneuroDesign model is applied to a sustainable engineering project in collaboration with a renewable energy company. The challenge presented to the students is to design an innovative, small-scale wind turbine suitable for urban environments. The project is structured around four two-week design sprints, each focusing on different aspects of the design: aerodynamics, structural integrity, power generation efficiency, and noise reduction. Students use advanced simulation software to optimize their designs, while also considering factors such as manufacturability, installation ease, and aesthetic appeal. The iterative nature of the sprints allows students to rapidly prototype using 3D printing and test their ideas, learning from failures and refining their designs based on performance data and user feedback. Industry mentors provide insights into market trends and regulatory requirements in the renewable energy sector. The entrepreneurial pitch sessions challenge students to present not only their technical solutions but also comprehensive business plans, including market analysis, cost projections, and potential revenue streams. This approach encourages students to consider the broader implications of their designs, including environmental impact, social acceptance, and economic viability. By the end of the project, students expected to gain valuable experience in sustainable engineering practices, interdisciplinary collaboration, and the commercialization of green technologies.

6. Discussion

The EntrepreneuroDesign model has the potential to significantly enhance student learning outcomes in mechanical engineering education. By integrating real-world projects, iterative design processes, and entrepreneurial thinking, students are likely to develop a more holistic understanding of engineering practice. This approach can lead to improved problem-solving skills, enhanced creativity, and a deeper appreciation for the interdisciplinary nature of engineering challenges (Dym et al., 2005). Moreover, the model's emphasis on entrepreneurship can foster innovation skills and business acumen, preparing students for diverse career paths in both established companies and startups (Duval-Couetil et al., 2016). The iterative nature of the design sprints may also contribute to increased resilience and adaptability in students, crucial traits in the rapidly evolving field of engineering. Additionally, the regular pitch sessions can significantly enhance students' communication skills, preparing them for leadership roles in their future careers (Neck & Greene, 2011).

Implementing the EntrepreneuroDesign model is not without challenges. One significant hurdle is the need for extensive industry partnerships, which require time and resources to establish and maintain (Ankrah & Al-Tabbaa, 2015). Faculty members may need additional training to effectively facilitate this new teaching approach, particularly in areas of entrepreneurship and design thinking. The model's emphasis on real-world projects may also introduce unpredictability into the curriculum, requiring flexibility in course scheduling and assessment methods. There might be resistance from traditional academics who view the focus on entrepreneurship as detracting from core engineering principles. Additionally, ensuring equitable access to resources and opportunities for all students within this project-based model could be challenging. Finally, aligning the pace of academic semesters with the often faster-moving industry projects may require careful planning and coordination (Kamp, 2016).

The EntrepreneuroDesign model has significant implications for curriculum design in mechanical engineering education. It necessitates a shift from traditional lecture-based courses to more project-based, interdisciplinary learning experiences. This may require restructuring of course sequences to allow for longer, more integrated project timelines (Kriewall & Mekemson, 2010). The curriculum would need to incorporate modules on entrepreneurship, design thinking, and professional communication alongside traditional engineering subjects. Assessment methods would need to evolve to evaluate not only technical knowledge but also skills such as creativity, teamwork, and entrepreneurial thinking. The model also implies a need for more flexible, modular course structures that can adapt to changing industry needs and project requirements. Furthermore, it may necessitate the integration of industry certifications or micro-credentials within the curriculum to enhance students' professional readiness (Sari et al., 2018).

The EntrepreneuroDesign model shows strong potential for aligning mechanical engineering education with current and future industry needs. By involving industry partners in project challenges and mentoring, the model ensures that students are working on relevant, up-to-date problems (Perkmann et al., 2013). The emphasis on entrepreneurial skills addresses the growing demand in the industry for engineers who can innovate and bring products to market. The iterative design process mirrors real-world product development cycles, preparing students for the fast-paced nature of modern engineering work. Moreover, the focus on interdisciplinary collaboration and communication skills aligns with the increasing importance of teamwork and cross-functional roles in industry. The model's integration of sustainability considerations, as seen in the case studies, also addresses the growing industry focus on environmentally responsible engineering practices. By fostering an entrepreneurial mindset, the model prepares students not only for traditional engineering roles but also for leadership positions and entrepreneurial ventures, reflecting the diverse career paths available in today's industry landscape (Duval-Couetil et al., 2016).

EntrepreneuroDesign distinguishes itself from traditional engineering education models by its holistic integration of design thinking, entrepreneurship, and industry-driven R&D practices. Unlike conventional project-based learning, which often relies on simulated scenarios, EntrepreneuroDesign incorporates real-world industry challenges, providing students with authentic experiences. While design thinking approaches in engineering education typically focus on user-centered design and iterative problem-solving, EntrepreneuroDesign goes further by explicitly incorporating entrepreneurial elements and market considerations. Compared to standalone entrepreneurship courses in engineering curricula, this framework seamlessly integrates entrepreneurial concepts into technical engineering projects, offering a more cohesive learning experience. The CDIO (Conceive-Design-Implement-Operate) framework, while comprehensive, does not emphasize entrepreneurial skills and market awareness to the same extent as EntrepreneuroDesign. Traditional industry-academia collaboration models often limit student interaction with industry partners, whereas EntrepreneuroDesign fosters continuous engagement through regular pitch sessions and mentorship.

EntrepreneuroDesign's unique features include its iterative design sprints that mimic real-world product development cycles, regular entrepreneurial pitch sessions for external feedback and pivoting, and a strong emphasis on market considerations and business model development. The framework's flexibility allows it to adapt to emerging industry trends and challenges, ensuring relevance in a rapidly evolving field. Benefits of this approach include enhanced student engagement through real-world, industry-relevant projects and the simultaneous development of both technical and entrepreneurial skills. Students gain improved industry readiness as they are exposed to current market demands and professional practices throughout their coursework. The potential for project continuation beyond the course, possibly leading to startups or industry innovations, offers additional motivation and real-world impact. Furthermore, EntrepreneuroDesign fosters stronger industry-academia relationships, creating ongoing collaboration opportunities and potential career pathways for students. By combining elements from various educational models and adding unique components, EntrepreneuroDesign offers a comprehensive framework that prepares students for the complex, interdisciplinary challenges of modern engineering practice while fostering an entrepreneurial mindset.

7. Future Research Directions

Future research should focus on rigorous empirical testing of the EntrepreneuroDesign model to validate its effectiveness in enhancing mechanical engineering education. This could involve implementing the model in multiple institutions and conducting comparative studies with traditional teaching methods. Researchers should employ mixed-method approaches, combining quantitative measures of student performance and skill development with qualitative assessments of student experiences and industry partner feedback (Borrego et al., 2014). Key areas to investigate include the model's impact on technical competencies, entrepreneurial skills, and overall student engagement. Additionally, studies should examine the effectiveness of different implementation strategies and identify best practices for integrating the model into existing curricula. Longitudinal studies tracking students from their introduction to the model through to their early career stages would provide valuable insights into the long-term efficacy of the approach (Duval-Couetil et al., 2016).

Assessing the long-term impact of the EntrepreneuroDesign model is crucial for understanding its value in preparing students for successful careers in engineering. Future research should track graduates who have experienced the model over an extended period, comparing their career trajectories, innovation output, and entrepreneurial activities with those of graduates from traditional programs. This could involve surveys, interviews, and analysis of career data to measure factors such as job satisfaction, career advancement, and involvement in startup ventures (Litzinger et al., 2011). Additionally, researchers should investigate the model's impact on industry-academia relationships, examining whether it leads to increased collaboration, research partnerships, or technology transfer. Long-term studies could also explore the model's influence on the engineering curriculum and teaching practices at institutional and national levels, assessing its potential to drive systemic change in engineering education (Kamp, 2016).

While the EntrepreneuroDesign model was developed for mechanical engineering education, future research should explore its adaptability to other engineering disciplines. This could involve pilot studies implementing modified versions of the model in fields such as electrical engineering, civil engineering, or computer science. Researchers should investigate how the core principles of the model can be tailored to address the specific needs and challenges of different engineering domains (Sheppard et al., 2009). Comparative studies across disciplines could provide insights into the model's versatility and identify discipline-specific factors that influence its effectiveness. Additionally, interdisciplinary applications of the model should be explored, examining how it might foster collaboration between students from different engineering fields and potentially non-engineering disciplines. This research direction could lead to the development of a more generalized framework for entrepreneurial engineering education that can be applied across various STEM fields (Neck & Greene, 2011).

Empirical validation of the EntrepreneuroDesign model-particularly through expert evaluation and external stakeholder feedback-remains a crucial next step for future research. Future studies should prioritize gathering and analyzing such data to rigorously assess the model’s effectiveness and applicability.

8. Conclusion

The EntrepreneuroDesign model represents a significant theoretical contribution to the field of mechanical engineering education. By integrating design thinking, entrepreneurship, and industry-driven R&D practices, it offers a novel framework for addressing the evolving needs of both students and industry (Kamp, 2016). The model's emphasis on iterative design sprints and entrepreneurial pitch sessions provides a structured approach to fostering innovation and market-oriented thinking within the engineering curriculum. This integration of technical and entrepreneurial skills addresses a critical gap in traditional engineering education, preparing students for the multifaceted challenges of modern engineering practice (Duval-Couetil et al., 2016). Furthermore, the model's focus on industry-partnered project challenges contributes to the ongoing discourse on effective industry-academia collaboration, offering a practical framework for meaningful engagement between these sectors (Perkmann et al., 2013). The EntrepreneuroDesign model also advances the theoretical understanding of how experiential learning and real-world problem-solving can be effectively incorporated into engineering education, building upon and extending existing pedagogical theories in the field (Kolb, 2014).

The EntrepreneuroDesign model holds significant potential for revolutionizing mechanical engineering education. By bridging the gap between academic learning and industry needs, it addresses one of the most persistent challenges in engineering education (Sheppard et al., 2009). The model's holistic approach to skill development, encompassing technical proficiency, innovation capabilities, and entrepreneurial acumen, aligns closely with the evolving demands of the engineering profession in the 21st century. Its emphasis on real-world problem-solving and iterative design processes has the potential to dramatically enhance student engagement and learning outcomes, preparing graduates who are not only technically competent but also innovative and adaptable (Dym et al., 2005). The integration of entrepreneurial thinking into the core curriculum could lead to a new generation of engineers who are equally comfortable in traditional engineering roles and entrepreneurial ventures, potentially driving innovation and economic growth in the engineering sector. Moreover, the model's flexible structure and emphasis on industry collaboration provide a framework for continuous curriculum evolution, ensuring that mechanical engineering education remains relevant and responsive to rapidly changing technological and market landscapes (Kamp, 2016). As such, the EntrepreneuroDesign model represents a promising path forward for mechanical engineering education, offering a transformative approach that could reshape how engineers are educated and prepared for their future careers.

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