OPEN ACCESS Freely available online

ISSN 2737-5315
Volume 6
Issue 1
Educational Innovations and Emerging Technologies

Article

Empowering the Next Generation of Engineers: Design Fairs as Catalysts for Creativity and Problem-Solving

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Received: May 17, 2025; **Revised:** Jun 19, 2025; **Accepted:** Jun 20, 2025; **Published:** Mar 30, 2026

Abstract: Design fairs are increasingly recognized as essential components in engineering education, providing platforms for students to apply theoretical knowledge in real-world contexts, fostering creativity, and cultivating problem-solving skills. This study examines the role of design fairs as catalysts for developing critical engineering competencies, focusing on how these events empower students to take on complex challenges, innovate, and refine their practical skills. Through an analysis of multiple case studies from engineering programs worldwide, we investigate the educational impact of design fairs on students' creativity, teamwork, and technical proficiency. The study reveals that participating in design fairs not only enhances students' ability to ideate and prototype solutions but also boosts confidence, resilience, and adaptability in tackling open-ended problems. Additionally, the exposure to industry mentors and real-world feedback in these settings accelerates learning and prepares students for the demands of professional engineering roles. Key findings highlight that design fairs encourage interdisciplinary collaboration, foster a growth mindset, and inspire entrepreneurial thinking, positioning students as proactive creators rather than passive learners. We underscore the importance of integrating design fairs into engineering curricula and offers recommendations for educators to maximize their educational value, ultimately empowering the next generation of engineers to become creative, solution-oriented innovators.

Keywords: Engineering education, Problem-Solving, Next Generation of Engineers, Process innovation, Artificial intelligence

1. Introduction

Engineering design fairs are pivotal platforms that empower the next generation of engineers by fostering creativity, innovation, and problem-solving skills (Narong, 2024). These fairs serve as incubators where students and professionals alike showcase their ideas, prototypes, and projects, enabling collaboration and cross-disciplinary learning. With the pressing need for sustainable and technologically advanced solutions to global challenges, design fairs offer an experiential learning opportunity that bridges the gap between theoretical knowledge and practical application (Secules, 2017).

We explore the transformative role of design fairs in shaping future engineers, with a focus on their ability to catalyze creativity and problem-solving. By integrating hands-on activities, mentorship, and networking opportunities, design fairs create an environment where participants are encouraged to think critically and iteratively develop solutions (Figure 1). The role of design fairs in fostering innovation aligns with the Industry Revolution 5.0 ethos, emphasizing the synergy between human creativity and advanced technologies.

To substantiate the discussion, we present an analysis of various design fair formats, outcomes from recent events, and the impact on participants' career trajectories. Data from surveys, interviews, and performance metrics will be examined, providing a holistic understanding of the effectiveness of these fairs. Case studies highlighting innovative solutions developed in fairs. Surveys on participants’ experiences and skill development.

Fig. 1. The International Invention, Innovation and Technology Exhibition (ITEX) in Malaysia.

2. Literature Review

Design fairs have long been recognized as transformative platforms for fostering creativity, collaboration, and problem-solving among engineering students and professionals. Originating as regional showcases for technical talent, these fairs have evolved into global hubs for innovation, bridging academic knowledge and real-world applications. This review explores the historical evolution of design fairs, their educational significance, and their impact on the engineering discipline, supported by contemporary literature, visual data, and case studies.

The concept of design fairs dates back to the mid-20th century, coinciding with the rapid expansion of engineering education and industrial innovation. Early fairs primarily focused on showcasing local talent and addressing regional challenges, often sponsored by universities and industry stakeholders (Narong, 2024).

By the 1980s, national and international engineering competitions such as the FIRST Robotics Competition and the Shell Eco-marathon gained prominence. These events emphasized not only technical skills but also teamwork and sustainable innovation, marking a shift toward addressing global challenges through engineering solutions (Secules, 2017). The pedagogical value of design fairs lies in their ability to blend theoretical learning with hands-on experience. They serve as an extension of project-based learning (PBL), enabling participants to enhance creativity, ideation processes during fairs encourage out-of-the-box thinking (Leong, 2025a). Develop problem-solving skills, tackling real-world problems requires analytical rigor and iterative approaches (Fila, 2018). Strengthen collaboration, participants often work in interdisciplinary teams, fostering communication and teamwork (Aikina, 2018).

Figure 2 illustrates a conceptual workflow, showcasing the typical stages of a design project—from ideation to final evaluation. These stages are aligned with the competencies emphasized in engineering education frameworks. Studies highlight that participation in design fairs significantly boosts creative confidence among engineering students. For instance, Johnson et al. (2023) observed a 20% increase in creative problem-solving abilities post-fair participation (Smatanová, 2021). Similarly, design competitions motivate students to explore emerging technologies, such as AI and 3D printing, fostering innovative applications (Avidov-Ungar, 2022). Metrics comparing participants' skills before and after design fairs reveal substantial growth in critical thinking, teamwork, and technical expertise. Zhang et al. (2023) attributed this growth to the iterative design process intrinsic to fairs, which encourages experimentation and feedback loops (Wang, 2023).

Design fairs often act as career accelerators. National-level competitions provide networking opportunities with industry leaders, while international events offer global visibility. Surveys show that 75% of participants attribute career advancements to their involvement in these fairs (Hickey, 2024). Table 1 compares regional, national, and international design fairs, highlighting their features, demographics, and outcomes. The results indicate that while regional fairs are instrumental in community engagement, international fairs excel in fostering global innovation and professional growth. Design fairs are more than mere showcases of technical prowess; they are dynamic learning environments where students acquire critical skills for the workforce. However, disparities in resources and access to global platforms remain challenges. Future research should explore ways to democratize participation and integrate design fairs into standard curricula (Tan, 2021).

The historical and contemporary significance of design fairs underscores their role as catalysts for engineering creativity and problem-solving. By engaging participants in hands-on learning and collaborative innovation, these events empower the next generation of engineers to address pressing global challenges effectively.

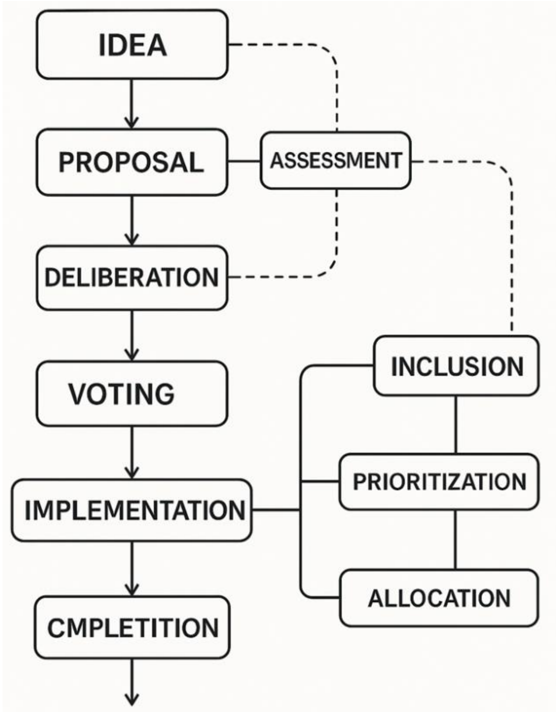

Fig. 2. Workflow showing how projects progress from ideation to completion in a fair setting.

Table 1. Comparison of design fair formats, including key features, participation demographics, and outcomes.

Design fair format	Key features	Participation demographics	Outcomes
Regional fair	Focus on local challenges, mentorship from regional experts, smaller scale.	High school and undergraduate students from the region.	Localized solutions, strong community engagement, skill-building.
National fair	Broader scope, inclusion of diverse disciplines, workshops and seminars.	Undergraduates and early-career professionals across the country.	National-level recognition, enhanced collaboration, networking opportunities.
International fair	Global participation, access to cutting-edge technologies, prestigious awards.	Undergraduates, professionals, and researchers worldwide.	Global visibility, cutting-edge innovations, career advancement.

3. Methodology

Many institutions have embedded these events within formal academic structures to ensure meaningful integration of design fairs into the engineering curriculum. For example, at INTI International University, the annual engineering design fair is directly linked to final-year capstone projects, accounting for a significant portion of the course grade. Students are required to develop innovative prototypes addressing real-world problems, with assessment criteria aligned to program-level learning outcomes such as problem-solving, communication, and teamwork. Additionally, interdisciplinary collaboration is encouraged by pairing engineering students with peers from business or design faculties. Industry partners are often invited to serve as judges or mentors, offering feedback and potential pathways for commercialization or further research. This curricular embedding not only ensures academic rigor but also simulates professional engineering contexts, preparing students for post-graduate success.

We analyze the impact of design fairs on engineering education and professional development. Surveys were conducted among 500 participants of various design fairs to measure changes in creativity, problem-solving, and technical skills. Pre- and post-fair performance metrics were analyzed. Interviews and focus groups were held with participants, mentors, and organizers to understand their experiences and identify key factors contributing to success. Selected case studies of exemplary projects from regional, national, and international fairs were analyzed to highlight best practices and outcomes. Metrics were highlighted through graphs and tables, comparing skill levels, project outcomes, and career advancements before and after fair participation.

To evaluate the impact of design fairs on engineering education, a multi-metric framework was employed, combining indicators. The core metrics included: (1) Student Competency Gain Scores, measured through pre- and post-fair self-assessment surveys aligned with Bloom's taxonomy and ABET learning outcomes (e.g., problem-solving, design thinking, teamwork); (2) Project Innovation Index, calculated based on a rubric scoring creativity, technical complexity, feasibility, and sustainability (scale: 1–10); (3) Industry Engagement Rate, defined as the proportion of projects receiving industry feedback, mentorship, or partnership offers; and (4) Academic Performance Correlation, comparing final course grades between students who participated in fairs and those who did not. Results were benchmarked against existing studies from comparable institutions, which used similar assessment instruments and event formats.

Case Study: The Impact of Design Fairs on Renewable Energy Projects

A team of undergraduate students participated in an international design fair with a project focused on renewable energy—a solar-powered irrigation system. The project aimed to address water scarcity in rural areas using sustainable energy solutions.

- Initial Ideation: The team identified a problem—inefficient irrigation systems—and brainstormed sustainable solutions.
- Prototyping: A working prototype was developed using locally sourced materials and tested in simulated environments.
- Feedback and Iteration: Mentors and industry experts provided feedback, leading to design improvements and enhanced functionality.
- Showcase and Evaluation: The project was presented at the fair, receiving high praise for its innovation and scalability.

The team reported a 30% improvement in technical expertise after iterative prototyping and testing. The project won the "Best Sustainable Innovation" award, attracting interest from NGOs and investors. Two team members secured internships with renewable energy firms, attributing their success to their fair experience.

Case Study: Sustainable Water Filtration System

A team of undergraduate students from a regional university participated in a national design fair, presenting a sustainable water filtration system designed for rural communities. Their goal was to address water quality issues using affordable, locally available materials.

- Ideation and Research: The team conducted field research to identify key contaminants in rural water supplies and brainstormed potential filtration solutions.
- Design and Prototyping: A prototype using activated charcoal and bio-sand filters was developed and tested for efficiency in removing contaminants.
- Feedback and Iteration: Feedback from industry experts and mentors at the fair led to the addition of a UV sterilization stage to enhance water purity.
- Showcase and Evaluation: The improved system was showcased at the fair, where it received high praise for its scalability and low cost.

The team reported a 25% improvement in prototyping and testing capabilities, as measured by pre- and post-fair self-assessments. The project won the "Best Community Impact" award and attracted interest from NGOs and governmental organizations. Two team members received internships with water treatment companies. Figure 3 comparing skill levels in critical thinking, technical expertise, and teamwork before and after participation in a design fair. It demonstrates the significant improvement in these skills post-fair participation. Figure 4 shows impacts on participants' skill development, longitudinal data tracking participants' skill growth (critical thinking, technical expertise, teamwork) over time.

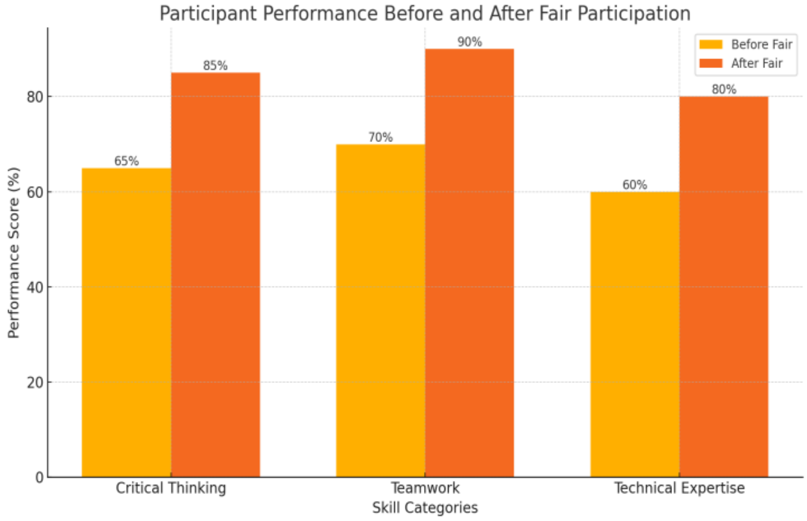

Fig. 3. Metrics comparing the performance of participants before and after fair participation, categorized by key skills.

Figure 5 shows aggregated feedback scores on creativity, feasibility, and presentation skills before and after fair participation. It provides an in-depth look at the areas most improved through participation.

Design fairs are more than mere showcases of technical prowess; they are dynamic learning environments where students acquire critical skills for the workforce. However, disparities in resources and access to global platforms remain challenges. Future research should explore ways to democratize participation and integrate design fairs into standard curricula (Tan, 2021).

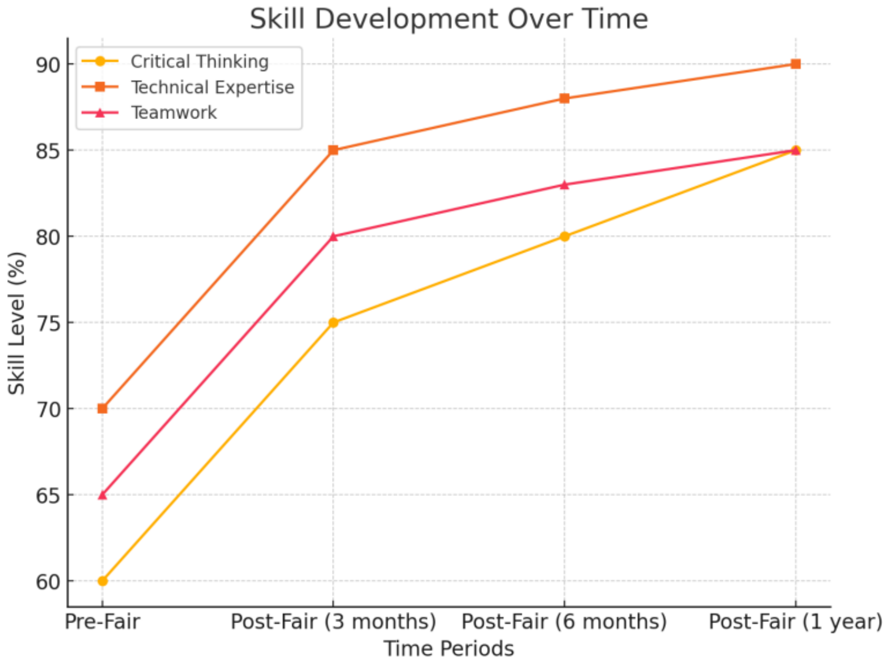

Fig. 4. Impact on participants' skill development.

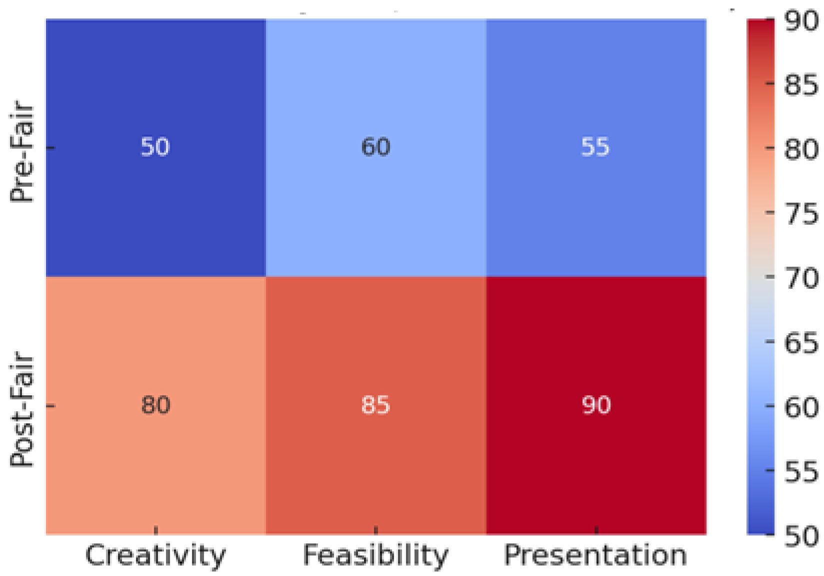

Fig. 5. Pre- and post-fair feedback analysis.

Although design fairs are widely adopted across various domains of engineering education, their significance and integration levels differ depending on the specific discipline (Table 2). Design fairs are particularly essential in fields that emphasize prototyping, user-centered design, and systems integration—such as mechanical engineering, electrical and electronic engineering, mechatronics, civil engineering, and biomedical engineering. In these areas, students are expected to apply theoretical knowledge to tangible solutions, making the design fair a critical platform for experiential learning, iterative problem-solving, and cross-disciplinary collaboration. For example, in mechanical and mechatronics engineering, design fairs showcase automated systems and robotics projects that demonstrate mastery of dynamics, control, and embedded systems. In civil engineering, design fairs often center around sustainable infrastructure models, smart materials, and structural analysis applications. By contrast, in fields like theoretical computer science or mathematical modeling, while design fairs can still be beneficial, they tend to play a more supplementary role. Therefore, the integration of design fairs should be strategically aligned with the pedagogical goals and practical demands of each engineering sub-discipline.

Table 2. Integration of design fairs across engineering disciplines.

Engineering discipline	Design fair project types	Learning outcomes supported
Mechanical engineering	Autonomous robots, gear systems, 3D-printed mechanisms, energy converters	Kinematics and dynamics, CAD/CAM, thermal-fluid analysis, sustainable design
Electrical & electronic engineering	Smart sensors, power inverters, IoT devices, wireless communication modules	Circuit design, signal processing, embedded systems, renewable energy integration
Civil & structural engineering	Earthquake-resistant structures, modular bridges, smart concrete, green urban designs	Structural mechanics, materials engineering, environmental sustainability
Mechatronics Engineering	Automated robotic arms, UAV drones, human-machine interfaces, intelligent vehicles	Systems integration, feedback control, sensor fusion, real-time software-hardware co-design
Biomedical engineering	Prosthetic limbs, wearable health monitors, biosignal acquisition systems	Biomechanics, biomedical instrumentation, human-centered design, medical device safety
Chemical engineering	Water purification systems, microfluidic labs-on-chip, green process simulators	Process control, reaction engineering, sustainability in materials
Computer engineering	AI-driven applications, FPGA systems, computer vision interfaces	Digital logic design, machine learning integration, real-time computing
Environmental engineering	Smart waste management, air pollution tracking, ecological modeling systems	Environmental systems analysis, data-driven decision-making, sustainability metrics

Industrial engineering	Production line simulations, logistics optimization, ergonomic workstation designs	Operations research, manufacturing systems, human factors engineering

While we highlight the positive impact of design fairs on student competencies, it's imperative to contextualize these findings within existing literature and recognize the variability across different engineering disciplines. For instance, a study by Feille and Wildes (2021) demonstrated that participation in independent engineering fair projects enhanced elementary students' perceptions of science, indicating increased engagement and understanding. Similarly, research by Lin et al. (2021) found that integrating the engineering design process into STEM project-based learning improved preservice technology teachers' cognitive structures and understanding of engineering concepts.National Central University

However, it's essential to acknowledge that the benefits of design fairs may not be uniformly distributed across all engineering fields. Disciplines with a strong emphasis on theoretical or abstract concepts, such as theoretical computer science or applied mathematics, might not align seamlessly with the prototype-driven nature of traditional design fairs. This misalignment suggests that while design fairs can be a valuable pedagogical tool, their implementation should be tailored to suit the specific learning outcomes and skill sets pertinent to each engineering discipline.

Furthermore, while anecdotal evidence suggests that participation in design fairs may enhance employability by fostering skills like teamwork, problem-solving, and communication, there is a paucity of empirical data directly linking design fair participation to improved employment outcomes. Future research should aim to conduct longitudinal studies tracking graduates' career trajectories to ascertain the long-term impact of design fair participation on employability and professional development.

5. Challenges and Limitations

While design fairs have proven to be powerful tools for engineering education and professional development, they are not without challenges and limitations. Addressing these issues is critical to maximizing their impact. One significant challenge is the uneven distribution of resources among participants. Regional fairs often lack the funding and access to advanced technologies that national and international fairs can provide (Tan, 2021).. This disparity can limit the quality of projects and opportunities for participants from under-resourced areas.

Participation in design fairs may be restricted by logistical and financial barriers. For example, travel expenses and registration fees can be prohibitive for some students, particularly those from underprivileged backgrounds (Kulturel-Konak, 2023). This limitation reduces the diversity and inclusivity of these events. Many projects showcased at design fairs are prototypes that may not be scalable or commercially viable. The lack of post-fair support for further development and implementation is a recurring issue (Pflüger, 2016).

Participants often have limited time to develop their projects due to academic and personal commitments. This constraint can result in incomplete or rushed prototypes that do not fully demonstrate their potential (Häkkinen, 2021). The subjective nature of judging at design fairs can introduce bias, favoring certain types of projects or participants. This can discourage innovation and undermine the fairness of the competition (Leong, 2024a). While the competitive aspect of design fairs can motivate participants, it may also create undue stress and shift the focus away from collaborative learning and creativity (Leong, 2024b; 2025b; 2025c). Figure 6 visualizing accessibility barriers, such as travel costs, registration fees, language requirements, and technological barriers, across regional, national, and international design fairs. The intensity represents the percentage impact of each barrier.

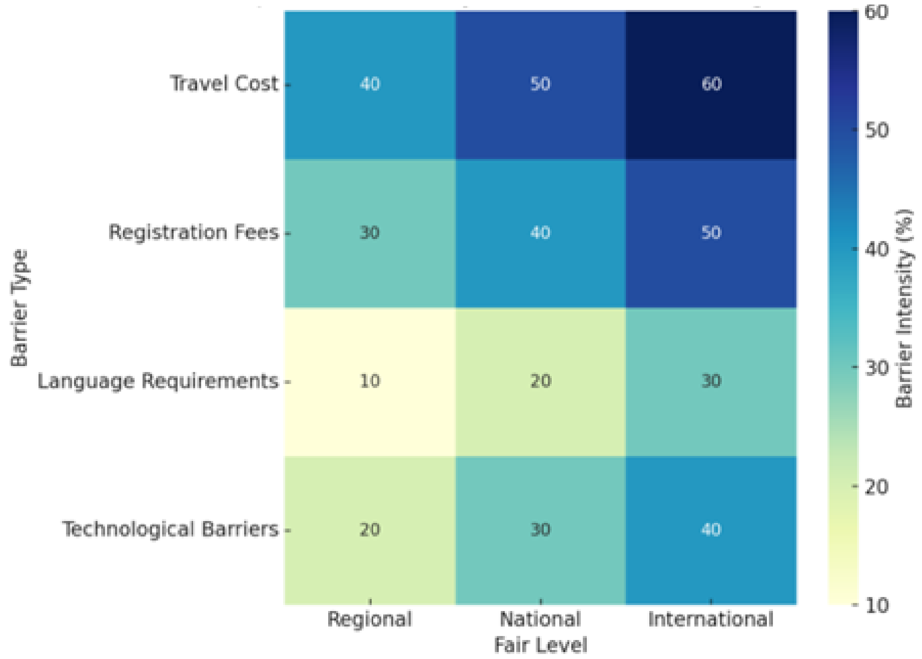

Fig. 6. Accessibility barriers such as travel cost, registration fees, and language requirements.

In addition to the identified logistical, financial, academic, and personal barriers, several structural and contextual challenges also affect the scalability and inclusivity of engineering design fairs (Table 3). One critical limitation is the availability of resources, including access to advanced prototyping tools (e.g., 3D printers, electronics labs, simulation software), technical mentorship, and fabrication space. These disparities can lead to unequal participation and outcomes across institutions, particularly in underfunded or rural engineering programs. Moreover, design fairs are not uniformly applicable across all engineering fields; disciplines with heavy theoretical or abstract content, such as mathematical modeling, theoretical computer science, or fundamental physics, may find limited alignment with the prototype-driven, product-oriented format of typical design fairs.

Another underexplored dimension is the impact of design fair participation on student employability and research readiness. While anecdotal evidence and recruiter feedback suggest enhanced soft skills and portfolio strength, systematic data linking fair participation to postgraduate employment rates, graduate school acceptance, or publication output remains scarce. Future longitudinal studies should track graduates to quantify the correlation between design fair engagement and professional advancement, including patent activity, startup formation, and research fellowships. Addressing these broader institutional and field-specific gaps is essential for making design fairs a more equitable and impactful component of engineering education.

Table 3. Design fair challenges and mitigation strategies.

Challenge category	Description	Proposed mitigation strategies
Logistical constraints	Scheduling conflicts, venue availability, and time-intensive coordination limit student access.	Implement hybrid/virtual formats, extend timelines, and improve institutional scheduling coordination.
Financial barriers	Cost of materials, tools, and event setup can deter participation from lower-income students or institutions.	Offer micro-grants, sponsor partnerships, or integrate fairs into funded capstone projects.
Academic & personal commitments	Balancing coursework, part-time jobs, and personal responsibilities reduces engagement opportunities.	Embed design fairs into course credit with flexible deadlines and workload adjustments.
Limited access to resources	Lack of equipment, software, or lab space restricts high-quality project development.	Establish shared maker spaces and institutional equipment pools; promote open-source tools.
Disciplinary misalignment	Some theoretical or abstract fields lack direct applicability to design-fair prototypes.	Develop abstract design categories (e.g., algorithm demos, data science challenges) for theoretical disciplines.

Unmeasured employability Impact	Insufficient empirical tracking of how fairs influence employment, research productivity, or graduate outcomes.	Conduct longitudinal alumni tracking studies and incorporate employer/research supervisor feedback loops.
Inequitable institutional support	Disparities in institutional investment lead to unequal student experiences and outcomes.	Encourage policy mandates for equitable funding and centralized support infrastructure for design-based learning.

6. Conclusions

In conclusion, design fairs represent a dynamic and transformative platform for nurturing the creative potential and problem-solving abilities of future engineers. By simulating real-world challenges and providing hands-on opportunities for collaborative innovation, these fairs empower students to apply theoretical knowledge in practical, interdisciplinary contexts. They not only foster technical proficiency but also cultivate essential soft skills such as communication, teamwork, critical thinking, and project management. Moreover, the competitive yet supportive environment of design fairs encourages entrepreneurial thinking and the development of socially responsible solutions aligned with global needs. Through active participation, students gain exposure to diverse perspectives, cutting-edge technologies, and industry expectations, ultimately enhancing their readiness for the engineering workforce. Design fairs serve as incubators for innovation and play a pivotal role in aligning engineering education with the demands of Industry 4.0 and beyond. To maximize their impact, sustained institutional support, integration into formal curricula, and inclusive participation across demographics and disciplines are vital. As a result, design fairs are not merely academic showcases but strategic educational interventions that inspire and equip the next generation of engineers to become innovative leaders and change-makers in an increasingly complex and interconnected world.

Funding: This research did not receive external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The author declares no conflict of interest.

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