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THE IMPACT OF INTEGRATING DESIGN THINKING COURSES INTO ENGINEERING CURRICULA

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Abstract

The incorporation of design thinking courses into engineering curricula has garnered considerable interest in recent years, as educators strive to equip students with the necessary skills to navigate the intricacies of contemporary engineering practice. This study provides a thorough examination of the effects of integrating design thinking principles into the field of engineering education. This research investigates the impact of design thinking courses on several aspects of students' academic performance, including problem-solving abilities, creativity, interdisciplinary collaboration, attitudes towards design and engineering, and career preparedness. By utilizing a comprehensive analysis of pertinent scholarly works and employing a systematic research approach including surveys, interviews, and case studies, this study investigates the theoretical foundations that support the incorporation of design thinking and assesses its efficacy in augmenting engineering education. The results suggest that the incorporation of design thinking principles has a beneficial impact on students' cognitive functions, facilitating the development of creative problem-solving strategies and cultivating a comprehensive comprehension of the design process. In addition, the incorporation of design thinking promotes collaboration across many fields and improves students' perspectives on design and engineering, ultimately enhancing their preparedness for careers and employability. Although design thinking has been found to have advantages, obstacles such as limited resources and inadequate faculty training continue to hinder its widespread implementation in engineering curricula. The paper provides suggestions for future research and practice, highlighting the importance of further investigation into novel teaching methods to promote creativity, innovation, and collaboration across different fields in engineering education.

Keywords: *Design thinking, engineering education, curriculum integration, interdisciplinary collaboration, problem-solving, creativity, innovation*

Introduction:

In the field of current engineering education, there has been a significant increase in the demand for graduates who are not only technically proficient but also possess the ability to solve problems creatively and have a profound comprehension of human-centered design principles. In response to this requirement, the incorporation of design thinking courses into engineering curricula has emerged as a crucial strategy for preparing students for the complex issues that are present in contemporary engineering practice. An approach to innovation that is human-centered and places an emphasis on empathy, iteration, and collaboration is called design thinking. This method provides engineers with a framework that allows them to effectively handle complicated challenges.

An in-depth analysis of the theoretical frameworks that drive the incorporation of design thinking into engineering education is presented in this study. This analysis is accomplished by doing a complete

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assessment of the current literature and combining it with empirical evidence obtained through surveys, interviews, and case studies. In addition to this, it investigates the advantages, disadvantages, and possible repercussions that could result from incorporating design thinking courses into engineering training programs. In the end, this research makes a contribution to the ongoing discussion on innovative pedagogical approaches in engineering education. It also offers insights for educators, curriculum designers, and policymakers who are working to improve the preparedness of engineering graduates for the ever-changing demands of the workforce in the 21st century.

Design Thinking:

Design thinking is a human-centred approach to innovation and problem-solving that emphasizes empathy, creativity, and collaboration. It is a structured process that guides individuals or teams through a series of steps aimed at understanding user needs, generating innovative solutions, and iteratively refining those solutions based on feedback. At its core, design thinking is about shifting the focus from finding the "right" answer to exploring a range of possibilities and discovering solutions that truly address the needs of users.

The design thinking process typically consists of several key stages. The first stage is empathy, where designers seek to understand the needs, motivations, and experiences of the people they are designing for. This often involves conducting interviews, observations, and other research methods to gain insights into users' perspectives. The next stage is defining the problem, where designers synthesize their research findings and identify the core challenges or opportunities they are addressing. This stage is crucial for framing the problem in a way that guides the subsequent ideation and prototyping phases.

The ideation phase is where designers generate a wide range of ideas for potential solutions. This is a highly creative and divergent phase, where quantity is valued over quality, and all ideas are considered valid. Once a diverse set of ideas has been generated, the prototyping phase begins. Prototyping involves creating low-fidelity representations of potential solutions, such as sketches, mock-ups, or prototypes, that can be shared and tested with users. This iterative process allows designers to quickly explore different concepts and gather feedback to inform further refinement.

Finally, the testing phase involves sharing prototypes with users and stakeholders to gather feedback and insights. This feedback is used to refine and iterate on the design, leading to improved solutions that better meet user needs. Importantly, the design thinking process is not linear, and designers may revisit and iterate on earlier stages as new insights emerge or as the project evolves.

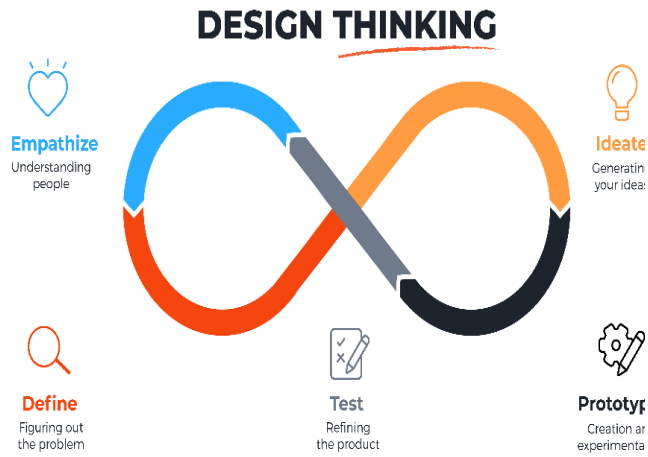

Fig. No. 1: The Design Thinking Process[8]

Design thinking promotes innovation, cooperation, and user-centered design. Design thinking prioritizes empathy and understanding to create user-centered solutions that meet their requirements. This human-centered approach frequently produces more imaginative and effective solutions that differentiate products and services. Design thinking also promotes interdisciplinary teamwork to solve complicated problems.

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Literature Review:

Within the context of teaching cryptography, Alhamdani (2016) investigates the application of design thinking, proposing an innovative technique to improving students' comprehension of intricate cryptographic ideas. In their 2014 study, Behm, Culvenor, and Dixon analyze the development of safe design thinking skills among engineering students. They highlight the significance of including safety considerations into the design process. The seminal explanation on design thinking that is provided by Brown (2008) outlines the concepts of design thinking and emphasizes the transformative potential of design thinking in a variety of fields. A study conducted by Greenhalgh (2016) investigates the influence that 3D printing has had on design thinking and design education, shedding light on the role that it plays in encouraging creativity and innovation. A comprehensive account of the evolution of design thinking is provided by Johansson-Skoldberg, Woodilla, and Çetinkaya (2013). They explore the history, present, and potential future trajectories of design thinking. An investigation into the effectiveness of engineering design thinking among high school students is conducted by Mentzer, Becker, and Sutton (2015). The researchers evaluate the students' performance and the knowledge they acquire through design-oriented activities. The purpose of each of these studies is to investigate the applications, implications, and efficacy of design thinking in a variety of educational settings. This is done in order to add to the larger discourse on design thinking. Historically, the fields of engineering and design were often siloed, with engineers and designers receiving distinct training and education. Mechanical Engineering (ME) stands as a testament to this tradition, boasting a rich history as an academic discipline focused on the principles of mechanics and machinery. However, as societal needs evolved and technology advanced, new academic disciplines emerged to address real-world problems more effectively. One significant development was the rise of Industrial Design (ID), particularly during the Bauhaus movement, in response to the industrialization of consumer products and the advent of mass-production techniques. This shift led to the gradual intertwining of disciplines, reflected in the nomenclature of academic programs such as "mechanical engineering design stream" or "industrial design engineering." This convergence suggested a promising synergy between industrial designers and mechanical engineers in tackling complex challenges collaboratively. However, successful interdisciplinary collaboration hinges upon a shared understanding of domain knowledge, presenting challenges for both practitioners and educators alike. Bridging this gap necessitates a closer examination of the core curricula developed by respective schools, fostering a common ground for interdisciplinary collaboration and innovation.

In a study performed by E. Acebo et al.[7] talks about articles on design thinking (DT) and design thinking in education (DTE).

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Table 1: Distribution of Articles on Design Thinking in Education across Various Journals

Journal	Number of Publications	Percentage of 83
Design Studies	6	6.70%
Thinking Skills and Creativity	4	4.40%
Education and Training	3	3.30%
Harvard Business Review	3	3.30%
International Journal of Art & Design Education	3	3.30%
Academy of Management Learning & Education	2	2.20%
Comunicar	2	2.20%
International Journal of Technology and Design Education	2	2.20%
Journal of Engineering Design	2	2.20%

Table 1 shows the distribution of design thinking in education publications across journals. It shows publications and percentage of each journal's 83 articles. The table shows that "Design Studies" has the most publications with 6, accounting for 6.70% of the total. "Thinking Skills and Creativity" and "Education and Training" follow with 4 articles each, accounting for 4.40% and 3.30% of the total. Other notable journals include "Harvard Business Review," "International Journal of Art & Design Education," "Academy of Management Learning & Education," "Comunicar," "International Journal of Technology and Design Education," and "Journal of Engineering Design," each publishing 3–2 articles with different percentages. In general, the table shows where design thinking in education has been extensively studied in academic publications.

Analysis of a Design Thinking Course in Curriculum: A sample curriculum is studied for a first-year B. Tech. course on Design Thinking and Innovation. Introduction to Design Thinking:

a) Design thinking encompasses a set of principles and a process that prioritize understanding user needs and preferences to drive innovation. Rooted in empathy, design thinking places the user at the center of the problem-solving process, emphasizing the importance of gaining insights into their experiences, behaviors, and aspirations. By adopting a user-centered approach, designers can uncover unmet needs, identify pain points, and generate solutions that address real-world challenges effectively. Ideation techniques play a crucial role in the design thinking process, facilitating the generation of creative ideas and solutions through brainstorming, mind mapping, and other creative exercises. These techniques encourage divergent thinking, enabling designers to explore a wide range of possibilities before converging on potential solutions.

b) User research skills are fundamental to the design thinking process, enabling designers to gather insights into user needs, preferences, and behaviors through methods such as interviews, observations, and surveys. Rapid prototyping and testing are integral components of design thinking, allowing designers to quickly iterate on ideas and gather

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feedback from users. By creating prototypes and testing them with end-users, designers can identify strengths and weaknesses in their designs, refine solutions based on user feedback, and iterate towards more effective solutions. This iterative approach fosters continuous improvement and ensures that solutions are aligned with user needs and preferences.

c) Cultivating a culture of innovation is essential for applying design thinking to engineering problems effectively. Design thinking encourages experimentation, risk-taking, and learning from failure, fostering a culture that values creativity and innovation. In engineering contexts, design thinking can be applied to tackle complex problems by breaking them down into manageable components, empathizing with end-users, and collaborating across disciplines to develop holistic solutions. Effective teamwork is crucial for applying design thinking in engineering practice, as it requires collaboration among engineers, designers, and other stakeholders to leverage diverse perspectives and expertise. By fostering a culture of innovation and collaboration, design thinking empowers engineering teams to develop solutions that address the needs of users and create value for society.

Design Thinking in Engineering Practice:

a) Design thinking offers a valuable framework for addressing engineering challenges by emphasizing empathy-driven design and systems thinking. By understanding the needs and preferences of end-users, engineers can develop solutions that are tailored to their specific requirements, leading to greater user satisfaction and acceptance. Systems thinking encourages engineers to consider the broader context in which their designs will operate, taking into account interdependencies, feedback loops, and unintended consequences. This holistic approach ensures that engineering solutions are sustainable, resilient, and aligned with broader societal goals.

b) Analyzing and evaluating design alternatives are critical steps in the design thinking process, enabling engineers to assess the feasibility, effectiveness, and impact of different solutions. Iterative design allows engineers to refine their designs based on feedback from users and stakeholders, continuously improving the quality and performance of their solutions over time. Continuous improvement is central to design thinking, encouraging engineers to learn from both successes and failures and iterate towards better solutions. By adopting an iterative approach to design, engineers can address evolving user needs, respond to changing market conditions, and stay ahead of the curve in a rapidly changing world.

c) Human factors and ergonomics play a significant role in engineering design, ensuring that products, systems, and environments are safe, efficient, and user-friendly. Design thinking emphasizes the importance of considering human factors in the design process, taking into account factors such as user capabilities, preferences, and limitations. Sustainability and ethics are also key considerations in engineering design, guiding engineers to develop solutions that minimize environmental impact, promote social equity, and adhere to ethical principles. Effective communication is essential for successful engineering design, enabling engineers to convey their ideas, gather feedback from users and stakeholders, and collaborate effectively with interdisciplinary teams. By integrating human factors, sustainability, ethics, and effective communication into the design process, engineers can develop solutions that meet the needs of users, are environmentally responsible, and contribute to the greater good of society.

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Design Thinking, Grassroot Level Innovations and Start ups:

Design thinking has played a pivotal role in the rise of startups by providing them with a framework for innovation and problem-solving that is both efficient and effective. Startups operate in dynamic and often uncertain environments, where the ability to identify and address unmet needs is critical for success. Design thinking offers a structured approach to understanding customer pain points, ideating solutions, and rapidly prototyping and iterating products or services based on user feedback.

One notable example of design thinking's impact on startups can be found in the grassroots innovation ecosystem in India. India is home to a vibrant community of grassroots innovators who develop low-cost, frugal solutions to address the needs of underserved communities. Many of these innovators lack formal training in engineering or design but possess an innate understanding of the problems faced by their communities. Design thinking has emerged as a powerful tool for empowering these innovators to refine and scale their solutions. For instance, the Honey Bee Network, founded by Prof. Anil Gupta at the Indian Institute of Management Ahmedabad, has been instrumental in documenting and disseminating grassroots innovations across India. By applying design thinking principles such as empathy, prototyping, and iteration, the Honey Bee Network has helped grassroots innovators refine their solutions, connect with potential collaborators and investors, and ultimately establish a status as impactful changemakers within their communities. Through initiatives like the National Innovation Foundation, which supports and promotes grassroots innovations, design thinking has catalyzed a culture of innovation and entrepreneurship at the grassroots level in India, driving social and economic development across the country.

By incorporating principles such as empathy, co-creation, and systems thinking into their business models, startups can develop offerings that address pressing social and environmental issues while also meeting the needs of their customers and stakeholders. This approach not only helps startups establish a strong social mission but also enables them to differentiate themselves in the market and attract socially conscious consumers and investors.

One compelling case study of design thinking's impact on grassroots innovation in India is the story of Arunachalam Muruganantham, often referred to as India's "Padman." Muruganantham, a school dropout from a rural village in Tamil Nadu, revolutionized menstrual hygiene in India by developing a low-cost sanitary pad-making machine. Inspired by his wife's struggles with menstrual hygiene, Muruganantham used design thinking principles such as empathy and prototyping to iterate on his initial designs and refine his solution. Despite facing skepticism and ridicule from his community, Muruganantham persisted in his efforts and eventually succeeded in developing a machine that could produce high-quality sanitary pads at a fraction of the cost of commercial alternatives. Today, Muruganantham's machines are used by thousands of women across India, empowering them with access to affordable and hygienic menstrual products and challenging taboos surrounding menstruation. Muruganantham's story highlights the transformative potential of design thinking in enabling grassroots innovators to address pressing social challenges and create meaningful change within their communities.

Design thinking catalyzes boosting grassroots level innovation by empowering individuals to identify, address, and solve pressing challenges within their communities. At the grassroots level, resources and expertise are often limited, making it essential to find innovative, low-cost solutions to local problems. Design thinking offers a structured yet flexible

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approach to problem-solving that emphasizes empathy, creativity, and iterative prototyping—all of which are well-suited to grassroots innovation efforts.

One way design thinking facilitates grassroots innovation is by encouraging a deep understanding of community needs and priorities. Through the empathetic exploration of end-users' experiences, grassroots innovators can gain valuable insights into the specific challenges they face. By engaging directly with community members and stakeholders, innovators can identify unmet needs, uncover latent desires, and co-create solutions that are truly tailored to the context in which they will be implemented.

Furthermore, design thinking promotes a culture of experimentation and iteration, which is essential for grassroots innovation. Innovators are encouraged to generate multiple ideas, prototype solutions quickly and inexpensively, and gather feedback from end-users to refine their designs. This iterative process allows innovators to test assumptions, learn from failures, and adapt their solutions based on real-world feedback—a crucial aspect of successful grassroots innovation where resources are scarce and risks are high.

In addition to fostering innovation at the grassroots level, design thinking also cultivates an inclination among students to take proactive initiatives in addressing social and environmental challenges. By exposing students to the principles and practices of design thinking, educators can inspire them to approach problems with creativity, empathy, and a bias towards action. Through hands-on projects and real-world experiences, students learn to identify opportunities for positive change, develop innovative solutions, and take proactive steps towards implementation.

Moreover, design thinking instils in students a sense of agency and empowerment, encouraging them to see themselves as agents of change rather than passive observers of the world around them. By equipping students with the skills and mindset necessary to tackle complex problems, design thinking empowers them to make a meaningful impact in their communities and beyond. Whether through grassroots initiatives, social entrepreneurship ventures, or advocacy efforts, students who embrace design thinking are better prepared to navigate the challenges of the 21st century and drive positive change in the world.

Conclusion:

Design Thinking workshops in engineering education improve creativity, teamwork, and critical thinking more than other innovative teaching methods, according to practical experiences. This shows the expanding importance of Design Thinking in education and society. Design Thinking is the leading method for solving complicated human needs challenges. Empathy, iterative problem-solving, and interdisciplinary collaboration make it revolutionary in engineering education and beyond. Design Thinking is primed for continued growth and adoption, delivering potential solutions to modern world's complex problems.

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